Request for the Taking of Marine Mammals Incidental to the Installation of the Block Island Wind Farm Export and Inter-Array Cables

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APPENDICES

Appendix A Underwater Noise Report

ACRONYMS AND ABBREVIATIONS

BIWF	Block Island Wind Farm
BOEM	Bureau of Ocean Energy Management
CeTAP	Cetacean and Turtles Assessment Program
CFR	Code of Federal Regulations
CRESLI	Coastal Research and Education Society of Long Island
CRMC	Rhode Island Coastal Resources Management Council
CRMP	Rhode Island Coastal Resources Management Program
cm	centimeter
dB	Decibel
dBL	decibel linear
DOI	U.S. Department of Interior
DON	U.S. Department of the Navy
DP	Dynamically Positioned
DWBI	Deepwater Wind Block Island, LLC
EFD	Energy Flux Density
EPA	U.S. Environmental Protection Agency
ER	Environmental Report
ESA	Endangered Species Act
Ft	foot
GPS	global positioning system
HDD	Horizontal Directional Drill
HDPE	High Density Polyethylene
Hz	Hertz
IHA	Incidental Harassment Authorization
In	inch
IUCN	World Conservation Union
IWC	International Whaling Commission
Km	kilometer
km^2	square kilometer
kHz	kilohertz
kJ	kilojoule
kN	kilo Newton
kV	kilovolts
kW	kilowatt
M	meter
m^3	cubic meter
Mi	mile
mi^2	square mile
MHW	mean high water
MMPA	Marine Mammal Protection Act
MW	megawatt
NEPA	National Environmental Policy Act
NERS	Northeast Regional Stranding Network
Nm	nautical mile
NOAA	National Oceanic and Atmospheric Administration

NOAA Fisheries	National Marine Fisheries Service
O&M	Operations and Maintenance
OCS	Outer Continental Shelf
Project	Block Island Wind Farm
Project Area	Block Island Wind Farm Project Area
PSO	Protected Species Observer
PTS	Permanent Threshold Shift
RAM	Range-Dependent Acoustic Model
RI Ocean SAMP	Rhode Island Ocean Special Area Management Plan
RIDEM	Rhode Island Department of Environmental Management
RMS	root mean square
sea2shore	sea2shore: The Renewable Link
SMA	Seasonal Management Area
SPUE	sightings per unit effort
TSS	total suspended solids
TTS	Temporary Threshold Shift
USACE	U.S. Army Corps of Engineers
WTG	wind turbine generator
WWF	World Wildlife Fund
yd^3	cubic yard
ZOI	Zone of Influence
μPa	micro-Pascal

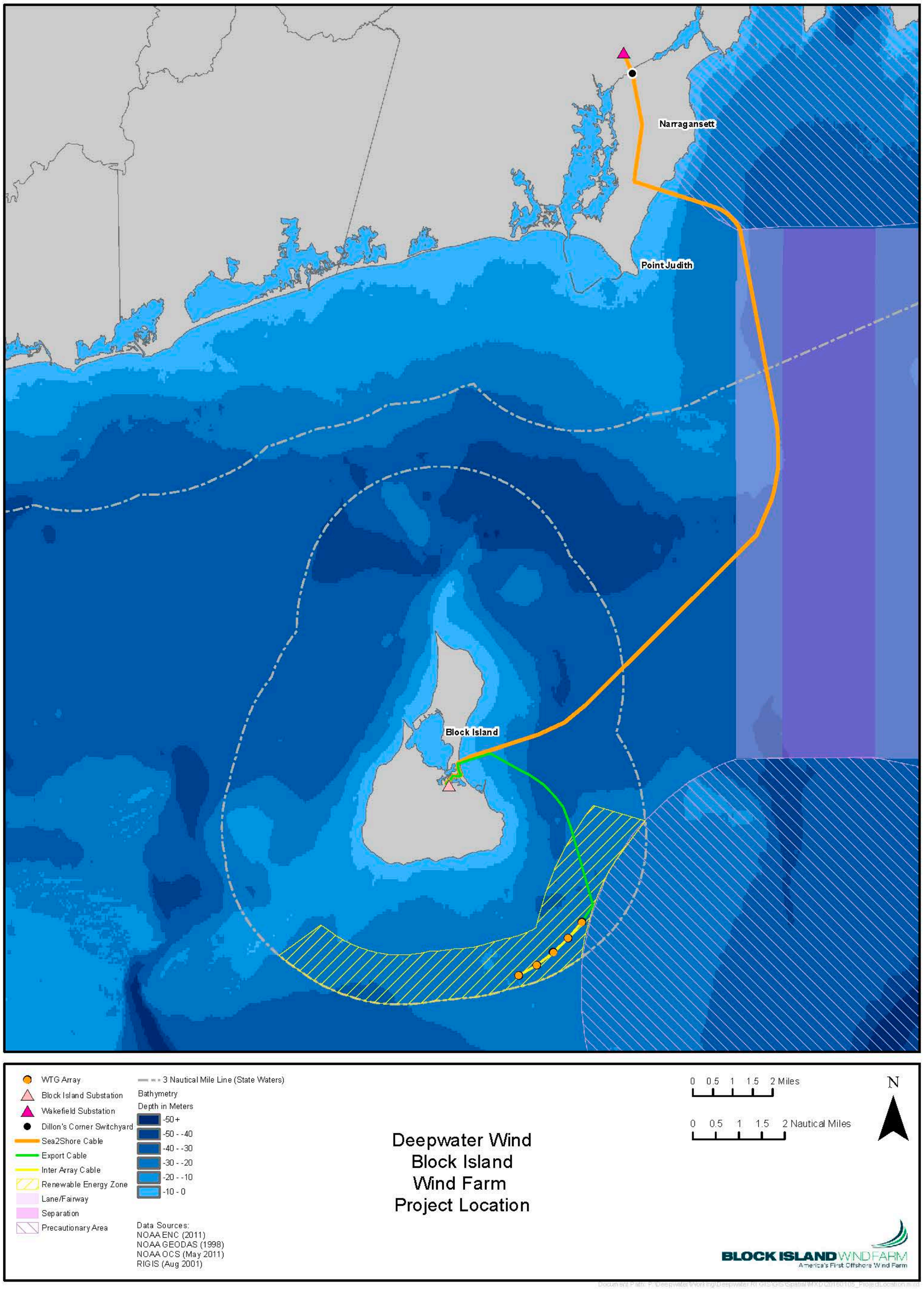
1.0 DESCRIPTION OF THE ACTIVITY

Deepwater Wind Block Island, LLC (DWBI) has begun construction of the Block Island Wind Farm (BIWF or Project), a 30 megawatt (MW) offshore wind farm located approximately 3 miles southeast of Block Island, Rhode Island (Figure 1-1). DWBI submits this request for Incidental Harassment Authorization (IHA) pursuant to Section 101(a)(5) of the Marine Mammal Protection Act (MMPA) and 50 Code of Federal Regulations (CFR) § 216 Subpart I to allow for the incidental harassment of small numbers of marine mammals resulting from the use of vessel thrusters while the cable laying vessel is keeping position by its Dynamic Position (DP) system during installation activities.

The regulations set forth in Section 101(a)(5) of the MMPA and 50 CFR § 216 Subpart I allow for the incidental taking of marine mammals by a specific activity if the activity is found to have a negligible impact on the species or stock(s) of marine mammals and will not result in immitigable adverse impact on the availability of the marine mammal species or stock(s) for certain subsistence uses. In order for the National Oceanic and Atmospheric Administration (NOAA) National Marine Fisheries Service (NOAA Fisheries) to consider authorizing the taking by U.S. citizens of small numbers of marine mammals incidental to a specified activity (other than commercial fishing), or to make a finding that incidental take is unlikely to occur, a written request must be submitted to the Assistant Administrator. Such a request is detailed in the following sections.

DWBI began construction at the BIWF in 2015 with the installation of five jacket foundations. Erection of the five wind turbine generators (WTGs), installation of the submarine cables (Inter-Array cable and Export Cable), and construction of the onshore components of the BIWF is planned for 2016. The scope of this application is limited to the use of vessel thrusters while the cable laying vessel is keeping position by its DP system during installation activities. For the BIWF this will apply to the installation of the submarine cables. The scope of potential harassment and the expected impacts to marine mammals are consistent with the assessment and results documented in the National Environmental Policy Act Environmental Assessment and associated Finding of No Significant Impact issued by the U.S. Army Corps of Engineers (USACE) on September 17, 2014. The use of DP vessel thrusters during the installation of the submarine cables was previously approved by NOAA Fisheries in an Incidental Harassment Authorization (IHA) issued to DWBI on September 3, 2014 and amended on June 11, 2015. That IHA expired on October 31, 2015, therefore DWBI is applying for a new IHA to cover the the use of vessel thrusters while the vessel is cable laying vessel keeping position by its DP system during 2016 installation activities.

Figure 1-1 BIWF Project Location



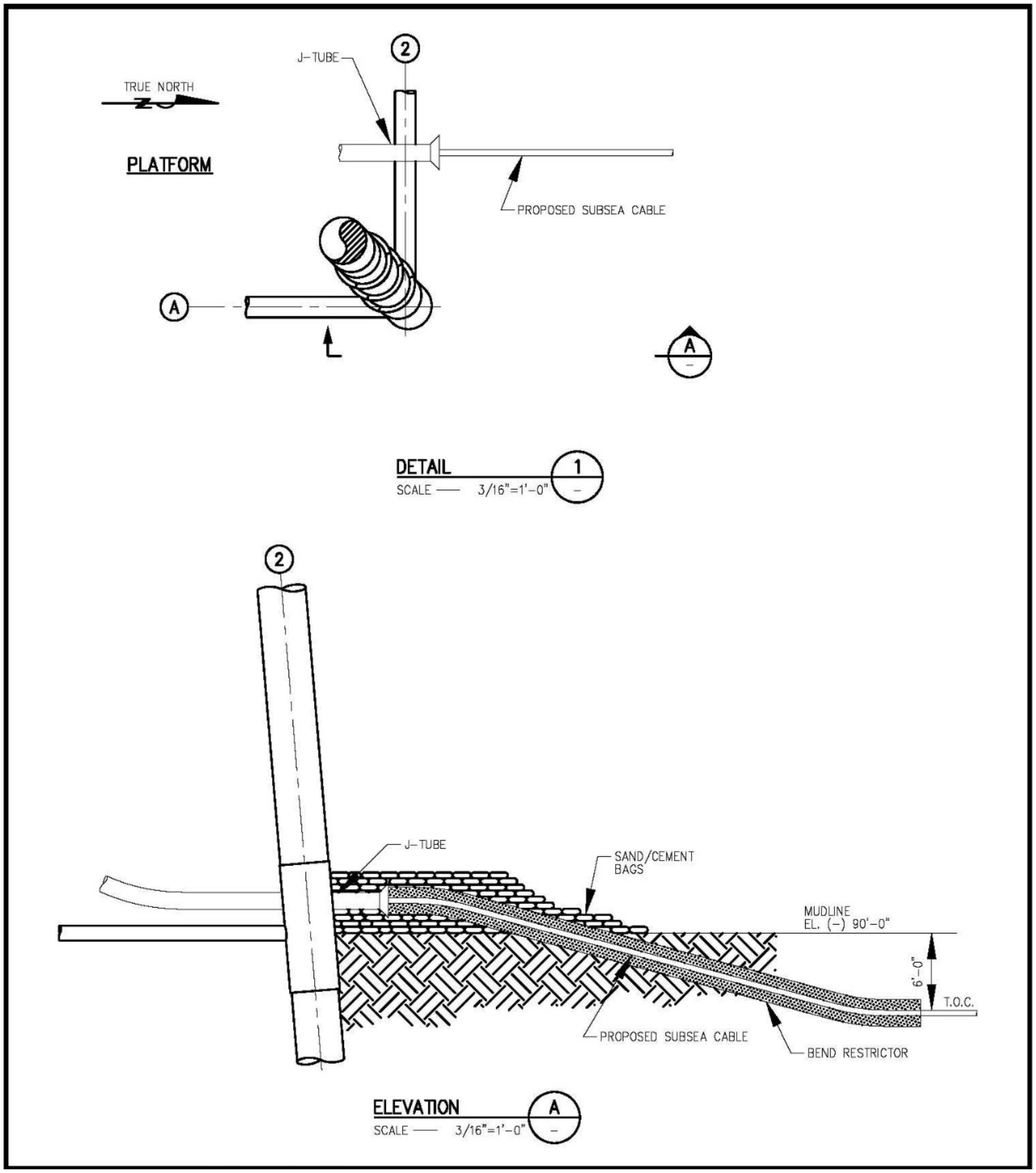
1.1 Project Facilities

The BIWF consists of five, 6 MW WTGs, a submarine cable interconnecting the WTGs (Inter-Array Cable), and a 34.5-kilovolt (kV) transmission cable from the northernmost WTG to an interconnection point on Block Island (Export Cable). Each WTG will be attached to the seafloor using a four-leg jacket foundation secured with four through-the-leg foundation piles. These 5 jacket foundations were installed in 2015. The submarine Inter-Array Cable and Export Cable will be comprised of a single, three-core cable that will carry 3-phase AC power. The cable will consist of three bundled aluminum or copper conductor cores surrounded by layers of insulating material within conducting and non-conducive metallic sheathing. The bundled cable will be approximately 6 in to 10 in (15.2 cm in to 25.4 cm) in diameter. Bags of sand and/or cement will also be placed on the seafloor to secure the Inter-Array Cable between the exit point and subsea burial point at the base of each the jacket foundation (Figure 1-2).

The BIWF is located an average of approximately 3 miles (mi) (4.8 kilometers (km)) southeast of Block Island, and approximately 16 mi (25.7 km) south of the Rhode Island mainland (Figure 1-1). The Inter-Array Cable, and a portion of the Export Cable will be located within the Rhode Island Renewable Energy Zone established by the CRMC through the Rhode Island Ocean Special Area Management Plan (RI Ocean SAMP). The Inter-Array Cable will connect the five WTGs, arranged in a radial configuration spaced approximately 0.5 mi (0.8 km) apart, for a total length of 2 mi (3.2 km) from the northernmost WTG to the southernmost WTG. The submarine Export Cable will originate at the northernmost WTG and travel 6.2 mi (10 km) to a manhole on Block Island. Water depths along the Export Cable submarine route range up to approximately 121 ft (36.9 m) in the deepest areas of the route.

Terrestrial cables, an interconnection switchyard (referred to as the BIWF Generation Switchyard) and other ancillary facilities associated with the BIWF will be located in the Town of New Shoreham (Block Island) in Washington County, Rhode Island. Construction staging and laydown for offshore construction will occur at the Port of Providence.

Figure 1-2 Cable Armoring at WTG Jacket Foundation J-Tube



1.2 Construction Activities

The WTG jacket foundations were installed in 2015. Erection of the five WTGs, installation of the submarine cables, and construction of the onshore components of the BIWF is planned for 2016. The scope of this application is limited to the use of vessel thrusters while the cable laying vessel is keeping position by its DP system during installation activities. For the BIWF this will apply to the installation of the submarine cables.

1.2.1 Offshore Cable Installation

A jet plow, supported by a DP cable installation barge, will be used to install the Export Cable and Inter-Array Cable below the seabed. Underwater noise produced by the thrusters associated with the DP vessel during cable installation activities has the potential to result in Level B Harassment of marine mammals.

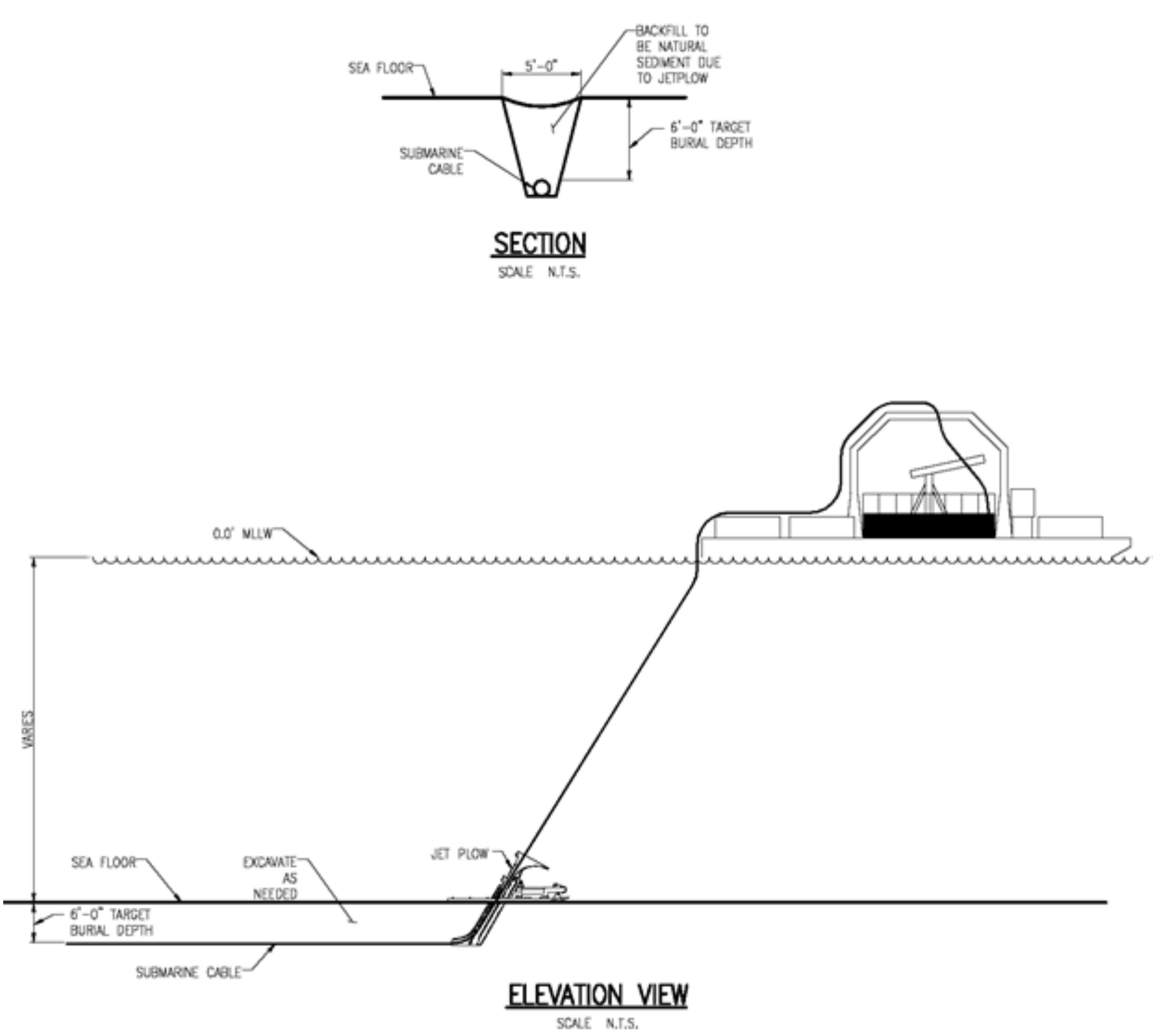
To accomplish the necessary burial depth, the jet plow will be positioned over the trench at the MLW mark on Crescent Beach and be pulled from shore by the cable installation barge. The jet plow will be pulled along the seafloor behind the cable-laying barge with assistance of a non-DP material barge (see Figure 1-3). High-pressure water from vessel-mounted pumps will be injected into the sediments through nozzles situated along the plow, causing the sediments to temporarily fluidize and create a liquefied trench. As the plow is pulled along the route behind the barge, the cable will be laid into the temporary, liquefied trench through the back of the plow. The trench will be backfilled by the water current and the natural settlement of the suspended material. Umbilical cords will connect the submerged jet plow to control equipment on the vessel to allow the operators to monitor and control the installation process and make adjustments to the speed and alignment as the installation proceeds across the water.

Depth of burial is controlled by adjusting the angle of the plow relative to the bottom. The Inter-Array Cable and Export Cable will be buried to a target depth of 6 ft (1.8 m) beneath the seafloor. The actual burial depth will depend on substrate encountered along the route and could vary from 4 ft to 8 ft (1.2 m to 2.4 m). If less than 4 ft (1.2 m) burial is achieved, DWBI may elect to install additional protection, such as concrete matting or rock piles.

At each of the WTGs, the Inter-Array Cable will be pulled into the jacket foundation through J-tubes installed on the sides of the jacket foundations. At the J-tubes, additional cable armoring such as sand bags and/or rocks will be used to protect the Inter-Array Cable (see Figure 1-2).

Depending on bottom conditions, weather, and other factors, installation of the Inter-Array Cable and Export Cable is expected to take up to 28 work days. This schedule assumes a 24-hour work window.

Figure 1-3 Submarine Cable Installation Detail



1.3 Remaining BIWF Construction Activities with Potential to result in Incidental Taking of Marine Mammals

The potential effects of underwater noise on marine mammals are federally managed by NOAA under the MMPA to minimize the potential for both harm and harassment. Under the MMPA, Level A harassment is statutorily defined as any act of pursuit, torment, or annoyance that has the potential to injure a marine mammal or marine mammal stock in the wild; however, the actionable sound pressure level is not identified in the statute. NOAA defines the Level A Harassment zone of injury to marine mammals as the range of received sound pressure levels from 180 linear decibels (dBL) referenced to 1 microPascal (µPa) root mean square (RMS), for mysticetes and odontocetes within the 180 decibels (dB) re 1µPa sound exposure limit, and 190 dBL re 1µPa for pinnipeds. This threshold considers instantaneous sound pressure levels at a given receiver location. The NOAA Fisheries 180 dBL re 1 µPa guideline is designed to protect all marine species from high sound pressure levels at any discrete frequency across the entire frequency spectrum. It is a very conservative criterion as it does not consider species-specific hearing capabilities.

The MMPA defines Level B harassment as any act of pursuit, torment, or annoyance that has the potential to disturb a marine mammal or marine mammal stock in the wild by causing disruption of behavioral patterns, including, but not limited to, migration, breathing, nursing, breeding, feeding, or sheltering. NOAA has defined the threshold level for Level B harassment at 120 dBL re 1 µPa for continuous noise and 160 dBL re 1 µPa for impulse noise. Within this zone, Project sound may approach or exceed ambient sound levels (i.e., threshold of perception or zone of audibility); however, actual perceptibility will be dependent on the hearing thresholds of the species under consideration and the inherent masking effects of ambient sound levels.

A summary of the NOAA Fisheries cause and effect noise criteria are summarized in Table 1-1.

Table 1-1 Summary of NOAA Fisheries Cause and Effect Noise Criteria (NOAA 2005)

	Criteria Level	Type
Level A Harassment	180 dBL re 1 µPa (RMS)	Absolute
Level B Harassment	160 re 1 µPa (RMS) 120 re 1 µPa (RMS)	Impulse Continuous

More recent regulatory criteria for marine mammals were promulgated by NOAA as part of a ruling on a permit application for a military sonar exercise (NOAA 2006). These criteria establish thresholds at which temporary or permanent hearing loss is expected for marine mammals. A temporary or reversible elevation in hearing threshold is termed a temporary threshold shift (TTS), while a permanent or unrecoverable reduction in hearing sensitivity is termed a permanent threshold shift (PTS). NOAA (2006) established a TTS of 195 dB re 1 µPa2-s and a PTS of 215 dB 1 µPa2-s for marine mammals based on the typical values for the additional dB above TTS required to induce PTS in experiments with terrestrial mammals. The revised TTS and PTS thresholds are defined as an energy flux density (EFD), which is the acoustic energy passing through a particular point per-unit decibel; therefore, TTS and PTS are given in the units of dB re 1µPa2-s, the integration of RMS sound pressure over a one-second duration. Being time energy-based, the TTS and PTS thresholds take into account cumulative sound exposure. A summary of the NOAA cause and effect noise criteria are summarized in Table 1-2.

Table 1-2 Summary of Cause and Effect Noise Criteria (NOAA 2006)

Received Sound Level	Effect
>120 dBL re 1 μPa (RMS)	Non-Specific Risk Level B Harassment
180 – 190 dBL re 1 μPa (RMS)	Non-Specific Risk Level A Harassment
195 dBL re μPa2-s	Temporary Threshold Shift (TTS)
215 dBL re μPa2-s	Permanent Threshold Shift (PTS)

The generation of underwater noise from DP vessel thruster use during submarine cable installation has the potential to result in Level B harassment, as described in Section 1.2.

To better understand both the level and extent of underwater noise and the potential to impact marine species, DWBI conducted a detailed underwater acoustic modeling assessment. This detailed assessment took into consideration:

- **Sound sources**: Sound sources were characterized as described in subsequent sections and Appendix A. Underwater acoustic modeling for noise producing activities was completed with the source positioned at mid-water depth for the purposes of the acoustic assessment.
- **Bathymetry**: Seabed topography was included in the model, which provided site-specific boundary conditions that affect underwater sound propagation and attenuation by shielding, refracting or reflecting sound (see Appendix A, Section 4.2).
- **Geoacoustic properties (e.g. hard rock, sand, mud) of the Project Area**[1]: The physical properties of the seabed were characterized (e.g., density, compressional and shear attenuation). These varying properties govern the sound speed and attenuation of acoustic signals through sediment and the model calculates the bottom loss and the reflecting differences in the speed of sound to determine bottom loss (see Appendix A, Section 4.3).
- **Time of Year:** The sound speed profile has an influence on sound attenuation and varies by location and month. The expected schedule of Project activities was consulted and the appropriate sound speed profiles were analyzed and applied to the model (see Appendix A, Section 4.4).

To evaluate effects from the operation of the DP thrusters, representative sound source data were reviewed to estimate representative thruster source level, which is dependent on the hydrodynamic and hydroacoustic design and depth of the thrusters on the vessel, and by power output (horsepower (HP)). The source level used in the assessment was adjusted to account for the actual expected power output of the DP thrusters, which is anticipated to be no more than 50 percent. This was accomplished by using the representative sound source level of the DP thruster at a 100 percent power output and then logarithmically scaling it to account for the anticipated power output. The logarithmic scale is considered conservative as it calculates an equal amount of percentage change between the source levels as they relate directly to power output, rather than attempting to determine the onset of cavitation for a vessel's thrusters[2], which cannot be accurately quantified and is often variable. The methodology used to determine and analyze sound generated by DP thrusters is further described in the Underwater Acoustic Assessment Report (Appendix A, Section 6.3). To be conservative, hydroacoustic modeling calculations were completed at three representative locations at water depths of 10 m, 20 m, and 40 m within the Project Area. Results of the analysis showed that at all depths, the estimated maximum critical distance to the 120 dBL MMPA threshold was approximately 4,750 m for 10 m water depth, 4,275 m for 20 m water depth, and 3,575 m for

[1] For the purposes of this IHA Application, the Project Area refers to the footprint of the BIWF facilities within state territorial waters of Rhode Island.

[2] Cavitation is the primary noise generated during thruster use.

40 m water depth (see Table 1-3). More information on results including figures displaying critical distance information can be found in Appendix A.

Table 1-3 Maximum Distances to MMPA Thresholds from DP vessel thrusters during submarine cable installation

Source	Distance to 180 dBL MMPA Threshold (m)	Distance to 160 dBL MMPA Threshold (m)	Distance to 120 dBL MMPA Threshold (m)
DP Vessel Maneuvering (Water Depth = 10 m)	<5	5	4,750
DP Vessel Maneuvering (Water Depth = 20 m)	<5	5	4,275
DP Vessel Maneuvering (Water Depth = 40 m)	<5	5	3,575

To verify the distance to the MMPA thresholds calculated by underwater acoustic modeling, DWBI has committed to conducting real-time underwater acoustic measurements of the DP vessel thrusters. Field verification of actual sound propagation will enable adjustment of the MMPA threshold level distances to fit actual construction conditions, if necessary. See Sections 11.0 for additional details on mitigation and monitoring.

2.0 DATES, DURATION AND LOCATION OF BIWF CONSTRUCTION

2.1 Construction Dates and Duration

Installation of the BIWF submarine cables is expected to take up to 28 work days. The submarine cable installation is scheduled to occur between April and October, 2016. Submarine cable installation will occur 24-hour/day, seven days/week.

2.2 Specific Geographic Region

The locations of the BIWF Project facilities have been selected based on detailed environmental and engineering site characterization studies. The offshore components of the BIWF will be located in state territorial waters. The WTGs, Inter-Array Cable, and a portion of the Export Cable will be located within the Rhode Island Renewable Energy Zone established by the CRMC through the RI Ocean SAMP. The WTGs will be arranged in a radial configuration spaced approximately 0.5 mi (0.8 km) apart. The Inter-Array Cable will connect the five WTGs for a total length of 2 mi (3.2 km) from the northernmost WTG to the southernmost WTG (Figure 1-1). Water depths along the WTG Array and Inter-Array Cable range up to approximately 75 to 93 ft (22.8 to 23.3 m) in the deepest areas. The Export Cable will originate at the northernmost WTG and travel 6.2 mi (10 km) to a manhole on Block Island. Water depths along the Export Cable submarine route range up to approximately 121 ft (36.9 m) in the deepest areas of the route.

3.0 SPECIES AND NUMBERS OF MARINE MAMMAL

Marine mammals known to traverse or occasionally visit the waters within the area of the Project include both threatened or endangered species, as well as those species that are not threatened or endangered. As shown in Table 3-1, 36 Endangered Species Act (ESA) and/or MMPA listed marine mammal species have the possible or confirmed occurrences within the marine waters of Rhode Island Sound. A description of the status and distribution of these species are discussed in detail in Section 4.0.

Table 3-1 Marine Mammals Known to Occur in the Marine Waters of Rhode Island Sound

Common Name	Scientific Name	NOAA Fisheries Status	Estimated Population	Stock
Toothed Whales (Odontoceti)				
Atlantic white-sided dolphin	*Lagenorhynchus acutus*	N/A	48,819	W. North Atlantic
Atlantic spotted dolphin	*Stenella frontalis*	N/A	44,715	W. North Atlantic
Bottlenose dolphin	*Tursiops truncates*	Northern coastal stock is Strategic [a/]	11,548	W. North Atlantic
Short-beaked common dolphin	*Delphinus delphis*	N/A	120,743	W. North Atlantic
Harbor porpoise	*Phocoena phocoena*	Strategic	79,833	Gulf of Maine/Bay of Fundy
Killer whale	*Orcinus orca*	N/A	Unknown	W. North Atlantic
False killer whale	*Pseudorca crassidens*	N/A	442	W. North Atlantic
Long-finned pilot whale	*Globicephala malaena*	N/A	26,535	W. North Atlantic
Short-finned pilot whale	*Globicephala macrorhynchus*	N/A	21,515	W. North Atlantic
Risso's dolphin	*Grampus griseus*	N/A	18,250	W. North Atlantic
Striped dolphin	*Stenella coeruleoalba*	N/A	46,882	W. North Atlantic
White-beaked dolphin	*Lagenorhynchus albirostris*	N/A	2,003	W. North Atlantic
Sperm whale	*Physeter macrocephalus*	Endangered	2,288	North Atlantic
Pigmy sperm whale	*Kogia breviceps*	Strategic	3,785 [b/]	W. North Atlantic
Dwarf sperm whale	*Kogia sima*	N/A	3,785 [b/]	W. North Atlantic
Cuvier's beaked whale	*Ziphius cavirostris*	Strategic	7,092 [c/]	W. North Atlantic
Blainville's beaked whale	*Mesoplodon densirostris*	Strategic	7,092 [c/]	W. North Atlantic
Gervais' beaked whale	*Mesoplodon europaeus*	Strategic	7,092 [c/]	W. North Atlantic
True's beaked whale	*Mesoplodon mirus*	Strategic	7,092 [c/]	W. North Atlantic
Bryde's whale	*Balaenoptera edeni*	N/A	N/A	W. North Atlantic
Northern bottlenose whale	*Hyperoodon ampullatus*	N/A	Unknown	W. North Atlantic
Beluga whale	*Delphinapterus leucas*	N/A	N/A	W. North Atlantic
Baleen Whales (Mysticeti)				
Minke whale	*Balaenoptera acutorostrata*	N/A	20,741	Canadian East Coast
Blue whale	*Balaenoptera musculus*	Endangered	Unknown	W. North Atlantic
Fin whale	*Balaenoptera physalus*	Endangered	1,618	W. North Atlantic
Humpback whale	*Megaptera novaeangliae*	Endangered	11,570	North Atlantic
North Atlantic right whale	*Eubalaena glacialis*	Endangered	465	W. North Atlantic
Sei whale	*Balaenoptera borealis*	Endangered	357	Nova Scotia
Earless Seals (Phocidae)				
Gray seals	*Halichoerus grypus*	N/A	348,900	North Atlantic
Harbor seals	*Phoca vitulina*	N/A	75,834	W. North Atlantic
Hooded seals	*Cystophora cristata*	N/A	Unknown	W. North Atlantic
Harp seal	*Phoca groenlandica*	N/A	8,300,000	North Atlantic
Ringed seal	*Pusa hispida*	N/A	N/A	Alaska
Order Sirenia				
West Indian manatee	*Trichechus manatus*	Endangered	3,802	Florida

Common Name	Scientific Name	NOAA Fisheries Status	Estimated Population	Stock

a/ A strategic stock is defined as any marine mammal stock: 1) for which the level of direct human-caused mortality exceeds the potential biological removal level; 2) which is declining and likely to be listed as threatened under the ESA; or 3) which is listed as threatened or endangered under the ESA or as depleted under the MMPA (http://www.ncseonline. org/nle/crsreports/biodiversity/biodv-11.cfm).

b/ This estimate may include both the dwarf and pygmy sperm whales.

c/ This estimate includes Cuvier's beaked whales and undifferentiated Mesoplodon spp. beaked whales.

Source: Waring et al. 2015; Warring et al 2013; Warring et al 2011;Warring et al 2010; RI SAMP 2011; Kenney and Vigness-Raposa 2009; NOAA Fisheries 2012

4.0 AFFECTED SPECIES STATUS AND DISTRIBUTION

As described in Section 3.0, of the 36 marine mammal species potentially inhabiting the waters of Rhode Island Sound, there are seven marine mammal species listed under the ESA with the potential to occur in Rhode Island waters: blue whale, fin whale, humpback whale, right whale, sei whale, sperm whale, and West Indian manatee. These species are highly migratory and do not spend extended periods of time in a localized area. The waters of Rhode Island (including the Project Area) are primarily used as a stopover point for these species during seasonal movements north or south between important feeding and breeding grounds. The typical migratory routes for right whales and other baleen whales lie further offshore and outside of the Project Area (Kenney and Vigness-Raposa 2009; RI Ocean SAMP 2011). While the fin, humpback, and right whales have the potential to occur within the Project Area, the blue and sei whales are more pelagic and/or northern species and their presence within the Project Area is unlikely. Additionally, the West Indian manatee has been sighted in Rhode Island waters; however, such events are extremely rare. With regard to sperm whales, while they are also known to occur occasionally in the region, their sightings are considered rare. However, based on a recent increase in sightings in the vicinity of the Project Area during 2015, they are included in the discussion below. Because the potential for the blue whale, sei whale, or West Indian manatee to occur within the Project Area during the marine construction period is unlikely, these species will not be described further in this analysis.

The following subsections provide additional information on the biology, habitat use, abundance, distribution, and the existing threats to the non-endangered or threatened and endangered marine mammals that are both common in Rhode Island waters and have the likelihood of occurring, at least seasonally, in the Project Area. These species include the minke, harbor porpoise, short-beaked common dolphin, Atlantic white-sided dolphin, harbor seals, and gray seals. In general, the remaining non-ESA whale species listed in Table 3-1 range outside the BIWF Project Area, usually in more pelagic waters, or are so rarely sighted that their presence in the Project Area is unlikely.

4.1 Toothed Whales (Odontonceti)

Sperm Whale (Physeter macrocephalus) – Endangered
Currently, there is no reliable estimate for the total number of sperm whales worldwide. The best estimate is that there are between 200,000 and 1,500,000 sperm whales, based on extrapolations from only a few areas that have useful estimates (NMFS 2006). Estimates show about 1,665 in the northern Gulf of Mexico, 14,000 in the North Atlantic, 80,000 in the North Pacific, and 9,500 in the Antarctic (NMFS 2006; Waring et al. 2009). For the western North Atlantic, the minimum population size has been estimated at 1,815 individuals (Waring et al. 2014).

Sperm whales are highly social, with a basic social unit consisting of 20 to 40 adult females, calves, and some juveniles (Rice 1989; Whitehead 2008). During their prime breeding period and old age, male sperm whales are essentially solitary. Males rejoin or find nursery groups during prime breeding season. While foraging, the whales typically gather in small clusters. Between diving bouts, sperm whales are known to raft together at the surface. Adult males often forage alone. Groups of females may spread out over distances greater than 0.5 nm when foraging. When socializing, they generally gather into larger surface-active groups (Jefferson et al. 2008; Whitehead 2003). In the Northern Hemisphere, the peak breeding season for sperm whales occurs between March and June, and in the Southern Hemisphere, the peak breeding season occurs between October and December (NMFS 2009).

This species primarily preys on squid and octopus and are also known to prey on fish, such as lumpsuckers and redfish. Although sperm whales are generalists in terms of prey, specialization does appear to occur in a few places. The main sperm whale feeding grounds are correlated with increased primary productivity caused by upwelling.

The sperm whale is thought to have a more extensive distribution than any other marine mammal, except possibly the killer whale. This species is found in polar to tropical waters in all oceans, from approximately 70° N to 70° S (Rice 1989; Whitehead 2003). It ranges throughout all deep oceans of the world, essentially from equatorial zones to the edges of the polar pack ice. In the Atlantic, sperm whales are found throughout the Gulf Stream and North Central Atlantic Gyre. The current abundance estimate for this species in the North Atlantic is 2,288 individuals. The species is listed as Endangered (Waring et al. 2015).

Sperm whales show a strong preference for deep waters (Rice 1989; Whitehead 2003). Their distribution is typically associated with waters over the continental shelf break and the continental slope and into deeper waters (Jefferson et al. 2008; Whitehead et al. 1992). Sperm whale concentrations near drop-offs and areas with strong currents and steep topography are correlated with high productivity. These whales occur almost exclusively found at the shelf break, regardless of season (NYDOS 2013). Sperm whales are somewhat migratory; however, their migrations are not as specific as seen in most of the baleen whale species. In the North Atlantic, there appears to be a general shift northward during the summer, but there is no clear migration in some temperate areas (Rice 1989; Whitehead 2003).

Harbor Porpoise (*Phocoena phocoena*) – Strategic

The harbor porpoise inhabits shallow, coastal waters, often found in bays, estuaries, and harbors. In the western Atlantic, they are found from Cape Hatteras north to Greenland. They are likely to occur frequently in Rhode Island waters within all seasons, but are most likely to reach their highest densities in spring when migration brings them toward the Gulf of Maine feeding grounds from their wintering areas offshore and in the mid-Atlantic (Kenney and Vigness-Raposa 2009). After April, they migrate north towards the Gulf of Maine and Bay of Fundy. Kenney and Vigness-Raposa (2009) report that harbor porpoises are among the most abundant cetaceans in Rhode Island coastal waters. Harbor porpoises are the smallest North Atlantic cetacean, measuring at only 1.4 to 1.9 m, and feed primarily on fish, but also prey on squid and crustaceans (Reeves and Read 2003; Kenney and Vigness-Raposa 2009). Sighting records from the 1978 to 1981 Cetacean and Turtle Assessment Program (CeTAP) surveys showed porpoises in spring exhibited highest densities in the southwestern Gulf of Maine in proximity to the Nantucket Shoals and western Georges Bank, with presence throughout the southern New England shelf and Gulf of Maine (CeTAP 1982). While strandings have occurred throughout the south shore of Long Island and coastal Rhode Island, many sightings have occurred offshore in the outer continental shelf (OCS) area (Kenney and Vigness-Raposa 2009). The North Atlantic harbor porpoise population is likely to be over 500,000 (Kenney and Vigness-Raposa 2009). The current population estimate for harbor porpoise in the Gulf of Maine/Bay of Fundy is 79,833 (Waring et al. 2015).

The most common threat to the harbor porpoise is from incidental mortality from fishing activities, especially from bottom-set gillnets. It has been demonstrated that the porpoise echolocation system is capable of detecting net fibers, but they must not have the "system activated" or else they fail to recognize the nets (Reeves et al. 2002). Roughly 365 harbor porpoises are killed by human-related activities in U.S. and Canadian waters each year. In 1999, a Take Reduction Plan to reduce harbor porpoise bycatch in U.S. Atlantic gillnets was implemented. The plan that pertains to the Gulf of Maine focuses on sink gillnets and other gillnets that can catch groundfish in New England waters. The ruling implements time and area closures, some of which are complete closures, as well as requiring pingers on multispecies gillnets. In 2001, the harbor porpoise was removed from the candidate species list for the ESA; a review of the biological status of the stock indicated that a classification of "Threatened" was not warranted (Waring et al. 2009). This species has been listed as "non-strategic" because average annual human-related mortality and injury does not exceed the potential biological removal (Waring et al. 2015).

Atlantic White-Sided Dolphin (*Lagenorhynchus acutus*) – Non-Strategic
The Atlantic white-sided dolphin is typically found at a depth of 330 ft (100 m) in the cool temperate and subpolar waters of the North Atlantic, generally along the continental shelf between the Gulf Stream and the Labrador current to as far south as North Carolina (Bulloch 1993; Reeves et al. 2002; Jefferson et al. 2008). They are the most abundant dolphin in the Gulf of Maine and the Gulf of St. Lawrence, but seem relatively rare along the North Atlantic coast of Nova Scotia (Kenney and Vigness-Raposa 2009).

Atlantic white-sided dolphins range between 2.5 and 2.8 m in length, with females being approximately 20 cm shorter than males (Kenney and Vigness-Raposa 2009). This species is highly social and is commonly seen feeding with fin whales (NOAA 1993). White-sided dolphins feed on a variety of small species, such as herring, hake, smelt, capelin, cod, and squid, with regional and seasonal changes in the species consumed (Kenney and Vigness-Raposa 2009). Sand lance is an important prey species for these dolphins in the Gulf of Maine during the spring. Other fish prey include mackerel, silver hake, herring, smelt, and several other varieties of gadoids (Kenney and Vigness-Raposa 2009). There are seasonal shifts in the distribution of Atlantic white-sided dolphins off the northeastern U.S. coast, with low abundance in winter between Georges Basin and Jeffrey's Ledge and very high abundance in the Gulf of Maine during spring. During the summer, Atlantic white-sided dolphins are most abundant between Cape Cod and the lower Bay of Fundy. During the fall, the distribution of Atlantic white-sided dolphins is similar to that in the summer, although they are less abundant (Department of the Navy [DoN] 2005). Recent population estimates for Atlantic white-sided dolphins in the Western North Atlantic Ocean places this species at 48,819 individuals (Waring et al. 2015). Seasonal abundances off the northeast U.S. in spring through fall are 38,000 to 42,000 animals (CeTAP 1982; Kenney and Vigness-Raposa 2009). This species can be found in Rhode Island waters during all seasons of the year, but is usually most numerous in areas farther offshore at depth range of 330 ft (100 m) (Kenney and Vigness-Raposa 2009; Bulloch 1993; Reeves et al. 2002). There have, however, been several unconfirmed reports of this species occurring in Narragansett Bay, usually between fall and winter (Kenney and Vigness-Raposa 2009).

The biggest human-induced threat to the Atlantic white-sided dolphin is bycatch, because they are occasionally caught in fishing gillnets and trawling equipment. An estimated average of 328 dolphins each year were killed by fishery-related activities during 2003 to 2007 (Waring et al. 2010). From 2008 through 2012, an estimated annual average of 116 dolphins per year were killed (Waring et al. 2015). Average annual fishery-related mortality and serious injury does not exceed the potential biological removal for this species; therefore, NOAA Fisheries considers this species as "non-strategic" (Waring et al. 2011; 2015).

Short-Beaked Common Dolphin (*Delphinus delphis*) – Non-Strategic
The short-beaked dolphin is one of the most widely distributed cetaceans and occurs in temperate, tropical, and subtropical regions (Jefferson et al. 2008). Short-beaked dolphins feed on squids and small fish, including species that school in proximity to surface waters as well as mesopelagic species found near the surface at night (World Conservation Union [IUCN] 2010; NatureServe 2010). They have been known to feed on fish escaping from fishermen's nets or fish that are discarded from boats (NOAA 1993). This

species is found between Cape Hatteras and Georges Bank from mid-January to May, although they migrate onto Georges Bank and the Scotian Shelf between mid-summer and fall, where large aggregations occur on Georges Bank in fall (Waring et al. 2007). These dolphins can gather in schools of hundreds or thousands, although the schools generally consist of smaller groups of 30 or fewer. They are eager bow riders and are active at the surface (Reeves et al. 2002). The short-beaked common dolphin feeds on small schooling fish and squid. While this dolphin species can occupy a variety of habitats, short-beaked common dolphins occur in greatest abundance within a broad band of the northeast edge of Georges Bank in the fall (Kenney and Vigness-Raposa 2009). According to the species stock report, the best population estimate for the western North Atlantic common dolphin is approximately 120,743 individuals (Waring et al. 2015). This species is the second most common cetacean in Rhode Island waters, and is known to occur during all four seasons (Kenney and Vigness-Raposa 2009).

Short-beaked common dolphins can be found either along the 650- to 6,500-ft (200- to 2,000-m) isobaths over the continental shelf and in pelagic waters of the Atlantic and Pacific Oceans. They are present in the western Atlantic from Newfoundland to Florida. The short-beaked common dolphin is especially common along shelf edges and in areas with sharp bottom relief such as seamounts and escarpments (Reeves et al. 2002). They show a strong affinity for areas with warm, saline surface waters. Off the coast of the eastern United States, they are particularly abundant in continental slope waters from Georges Bank southward to about 35 degrees north (Reeves et al. 2002) and usually inhabit tropical, subtropical, and warm-temperate waters (Waring et al. 2009).

The short-beaked common dolphin is also subject to bycatch. It has been caught in gillnets, pelagic trawls, and during longline fishery activities. During 2004 to 2008, it was estimated that on average approximately 167 dolphins were killed each year by human activities (Waring et al. 2010). This number increased to 289 dolphins during 2008 to 2012 (Waring et al. 2015). This species is also the most common dolphin species to be stranded on the Rhode Island Coast (Kenney and Vigness-Raposa 2009). Average annual fishery-related mortality and serious injury does not exceed the potential biological removal for this species; therefore, NOAA Fisheries considers this species as "non-strategic" (Waring et al. 2009; 2010; 2015).

4.2 Baleen Whales (Mysticeti)

North Atlantic Right Whale (*Eubalaena glacialis*) – Endangered

The North Atlantic right whale is a strongly migratory species that moves annually between high-latitude feeding grounds and low-latitude calving and breeding grounds. This species was listed as a federally endangered species in 1970 and is one of the most endangered large whale species in the world. The North Atlantic right whale has seen a nominal 2 percent recovery rate since it was listed as a protected species (NOAA Fisheries 2015). This is a drastic difference from the stock found in the Southern Hemisphere, which has increased at a rate of 7 to 8 percent (Knowlton and Kraus 2001). The historic range of this species reached its southern terminus between Florida and northwestern Africa and its northern terminus between Labrador and Norway (Kenney 2002). The present range of the western North Atlantic right whale population extends from the southeastern United States, which is utilized for wintering and calving, to summer feeding and nursery grounds between New England and the Bay of Fundy and the Gulf of St. Lawrence (Kenney 2002; Waring et al. 2007). A right whale satellite tracking study within the northeast Atlantic (Baumgartner and Mate 2005) reported that this species often visited waters exhibiting low bottom water temperatures, high surface salinity, and high surface stratification, most likely for higher food densities. The winter distribution of North Atlantic right whales is largely unknown, although offshore surveys have reported between one and 13 detections annually in northeastern Florida and southeastern Georgia (Waring et al. 2007). A few documented events of right whale calving have been from shallow coastal areas and bays (Kenney 2002). North Atlantic right whales may be found in feeding grounds within New England waters between February and May, with peak abundance in late March (NOAA 2005). While in New England, right whales feed mostly on copepods belonging to the Calanus and Pseudocalanus genus (Waring et al. 2007). Right whales are considered grazers as they swim slowly with their mouths open. They are the slowest swimming whales and can only reach speeds up to 10 mi (16 km) per hour. They can dive at least 1,000 ft (300 m) and stay submerged for typically 10 to 15 minutes, feeding on their prey below the surface (ACSonline 2004).

The North Atlantic right whale was the first species targeted during commercial whaling operations and was the first species to be greatly depleted as a result of whaling operations (Kenney 2002). North Atlantic right whales were hunted in southern New England until the early twentieth century. Shore-based whaling in Long Island involved catches of right whales year-round, with peak catches in spring during the northbound migration from calving grounds off the southeastern United States to feeding grounds in the Gulf of Maine (Kenney and Vigness-Raposa 2009). Abundance estimates for the North Atlantic right whale population vary. From the 2003 United States Atlantic and Gulf of Mexico Marine Mammal Stock Assessments, there were only 291 North Atlantic right whales in existence, which is less than what was reported in the Northern Right Whale Recovery Plan written in 1991 (NOAA Fisheries 1991a; Waring et al. 2004). This is a tremendous difference from pre-exploitation numbers, which are thought to be around 1,000 individuals. When the right whale was finally protected in the 1930s, it is believed that the North Atlantic right whale population was roughly 100 individuals (Waring et al. 2004). In 2009, the Western North Atlantic population size was estimated to be at least 444 individuals (Waring et al. 2013)

Contemporary anthropogenic threats to right whale populations include fishery entanglements and vessel strikes, although habitat loss, pollution, anthropogenic noise, and intense commercial fishing may also negatively impact their populations (Kenney 2002). Ship strikes of individuals can impact northern right whales on a population level due to the intrinsically small remnant population that persists in the North Atlantic (Laist et al. 2001). Between 2002 and 2006, a study of marine mammal strandings and human-induced interactions reported that right whales in the western Atlantic were subject to the highest proportion of entanglements (25 of 145 confirmed events) and ship strikes (16 of 43 confirmed occurrences) of any marine mammal studied (Glass et al. 2008). Bycatch of North Atlantic right whale has also been reported in pelagic drift gillnet operations by the Northeast Fisheries Observer Program, however, no mortalities have been reported (Glass et al. 2008). From 2006 through 2010, the minimum rate of annual human-caused mortality and serious injury to this species averaged 3.0 per year (Waring et al. 2013). From 2008 through 2012, the minimum rate of annual human-caused mortality and serious injury to this species from fishing entanglements averaged 3.65 per year, while ship strikes averaged 0.9 whales per year (Waring et al. 2015). The NOAA marine mammal stock assessment for 2014 reports that the low annual reproductive rate of right whales, coupled with small population size, suggests anthropogenic mortality may have a greater impact on population growth rates for the species than for other whales (Waring et al. 2015).

Most ship strikes are fatal to the North Atlantic right whales (Jensen and Silber 2004). Right whales have difficulty maneuvering around boats and spend most of their time at the surface, feeding, resting, mating, and nursing, increasing their vulnerability to collisions. Mariners should assume that North Atlantic right whales will not move out of their way nor will they be easy to detect from the bow of a ship for they are dark in color and maintain a low profile while swimming (World Wildlife Fund [WWF] 2005). To address potential for ship strike, NOAA Fisheries designated the nearshore waters of the Mid-Atlantic Bight as the Mid-Atlantic U.S. Seasonal Management Area (SMA) for right whales. NOAA Fisheries requires that all vessels 65 ft (19.8 m) or longer must travel at 10 knots or less within the right whale SMA from November 1 through April 30 when right whales are most likely to pass through these waters (NOAA 2010). The WTG Array and portions of the Export Cable are located within the right whale Mid-Atlantic SMA.

Right whales have been observed in or near Rhode Island during all four seasons; however, they are most common in the spring when they are migrating and in the fall during their southbound migration (Kenney and Vigness-Raposa 2009). Based on modeled seasonal abundance patterns conducted in support of the RI Ocean SAMP, right whales have the potential to occur in the Project Area during these seasons (Kenney and Vigness-Raposa 2009).

Humpback Whale (*Megaptera novaeangliae*) – Endangered

The humpback whale was listed as endangered in 1970 due to population decrease resulting from overharvesting. Humpback whales feed on small prey that is often found in large concentrations, including krill and fish such as herring and sand lance (Waring et al. 2007; Kenney and Vigness-Raposa 2009). Humpback whales are thought to feed mainly while migrating and in summer feeding areas; little feeding is known to occur in their wintering grounds. Humpbacks feed over the continental shelf in the North Atlantic between New Jersey and Greenland, consuming roughly 95 percent small schooling fish and 5 percent zooplankton (i.e., krill), and they will migrate throughout their summer habitat to locate prey (Kenney and Winn 1986). They swim below the thermocline to pursue their prey, so even though the surface temperatures might be warm, they are frequently swimming in cold water (NOAA Fisheries 1991b). Humpback whales from all of the North Atlantic migrate to the Caribbean in winter, where calves are born between January and March (Blaylock et al. 1995).

Humpback whales exhibit consistent fidelity to feeding areas within the northern hemisphere (Stevick et al. 2006). There are six subpopulations of humpback whales that feed in six different areas during spring, summer and fall. These populations can be found in the Gulf of Maine, the Gulf of St. Lawrence, Newfoundland/Labrador, western Greenland, Iceland, and Norway (Waring et al. 2007). The highest abundance for humpback whales is distributed primarily along a relatively narrow corridor following the 328-ft (100-m) isobath across the southern Gulf of Maine from the northwestern slope of Georges Bank, south to the Great South Channel, and northward alongside Cape Cod to Stellwagen Bank and Jeffreys Ledge. Humpback whales migrate from these feeding areas to the West Indies (including the Antilles, the Dominican Republic, the Virgin Islands and Puerto Rico) where they mate and calve their young (NMFS 1991b; Waring et al. 2007). While migrating, humpback whales utilize the mid-Atlantic as a migration pathway between calving/mating grounds to the south and feeding grounds in the north (Waring et al. 2007).

Humpback whales were hunted as early as the seventeenth century, with most whaling operations having occurred in the nineteenth century (Kenney and Vigness-Raposa 2009). Before whaling activities, it was thought that the abundance of whales in the North Atlantic stock was in excess of 15,000 (Nowak 2002). By 1932, commercial hunting within the North Atlantic may have reduced the humpback whale population to as little as 700 individuals (Breiwick et al. 1983). Humpback whales were commercially exploited by whalers throughout their whole range until they were protected in the North Atlantic in 1955 by the International Whaling Commission (IWC) ban. Humpback whaling ended worldwide in 1966 (NatureServe 2010). Contemporary anthropogenic threats to humpback whales include fishery entanglements and vessel strikes. Glass et al. (2008) reported that between 2002 and 2006, humpback whales belonging to the Gulf of Maine population were involved in 77 confirmed entanglements with fishery equipment and nine confirmed ship strikes. Humpback whales that were entangled exhibited the highest number of serious injury events of the six species of whale studied by Glass et al. (2008). A whale mortality and serious injury study conducted by Nelson et al. (2007) reported that the minimum annual rate of anthropogenic mortality and serious injury to humpback whales occupying the Gulf of Maine was 4.2 individuals per year. During this study period, humpback whales were involved in 70 reported entanglements and 12 vessel strikes, and were the most common dead species reported. This number has increased to 10.3 animals per year between 2008 and 2012 (Waring et al. 2015). The humpback whale population within the North Atlantic has been estimated to include approximately 11,570 individuals (Waring et al. 2015). Through photographic population estimates, humpback whales within the Gulf of Maine (the only region where these whales summer in the United States) have been estimated to consist of 600 individuals in 1979 (NOAA Fisheries 1991b). According to the species stock assessment report, the best estimate of abundance for the Gulf of Maine stock of humpback whales is 847 individuals (Waring et al. 2015).

Humpbacks occur off southern New England in all four seasons, with peak abundance in spring and summer. Based on modeled seasonal abundance patterns conducted in support of the RI Ocean SAMP, humpback whales have the potential to occur in the Project Area during these seasons (Kenney and Vigness-Raposa 2009).

The species is listed as Endangered due to the depletion of its population from whaling (NOAA Fisheries 1991b). A recovery plan has been written and is currently in effect (NOAA Fisheries 1991b).

Fin Whale (*Balaenoptera physalus*) – Endangered
The fin whale was listed as federally endangered in 1970. Fin whales' range in the North Atlantic extends from the Gulf of Mexico, Caribbean Sea, and Mediterranean Sea in the south to Greenland, Iceland, and Norway in the north (Jonsgård 1966; Gambell 1985a). They are the most commonly sighted large whales in continental shelf waters from the Mid-Atlantic coast of the United States to Nova Scotia (Sergeant 1977; Sutcliffe and Brodie 1977; CETAP 1982; Hain et al. 1992; Waring et al. 2008). Fin whales, much like humpback whales, seem to exhibit habitat fidelity (Waring et al. 2007; Kenney and Vigness-Raposa 2009). However, fin whales habitat use has shifted in the southern Gulf of Maine, mostly likely due to changes in the abundance of sand lance and herring, both of which are major prey species along with squid, krill, and copepods (Kenney and Vigness-Raposa 2009). While fin whales typically feed in the Gulf of Maine and the waters surrounding New England, mating and calving (and general wintering) areas are largely unknown (Waring et al. 2007). Fin whale abundance off the coast of the northeastern United States is highest between spring and fall, with some individuals remaining during the winter (Hain et al. 1992). A recent estimate of fin whale abundance conducted between Georges Bank and the Gulf of St. Lawrence during the feeding season in August 2006 places the western North Atlantic fin whale populations at 2,269 individuals (Waring et al. 2007). Fin whales are the second largest living whale species on the planet (Kenney and Vigness-Raposa 2009). The gestation period for fin whales is approximately 11 months and calve births occur between late fall and winter. Females can give birth every two to three years.

Present threats to fin whales are similar to other whale species, namely fishery entanglements and vessel strikes. Fin whales seem less likely to become entangled than other whale species. Glass et al. (2008) reported that between 2002 and 2006, fin whales belonging to the Gulf of Maine population were involved in only eight confirmed entanglements with fishery equipment. Furthermore, Nelson et al. (2007) reported that fin whales exhibited a low proportion of entanglements (eight reported events) during their 2001 to 2005 study along the western Atlantic. On the other hand, vessel strikes may be a more serious threat to fin whales. Eight and ten confirmed vessel strikes with fin whales were reported by Glass et al. (2008) and Nelson et al. (2007), respectively. This level of incidence was similar to that exhibited by the other whales studied. Conversely, a study compiling whale/vessel strike reports from historical accounts, recent whale strandings, and anecdotal records by Laist et al. (2001) reported that of the 11 great whale species studied, fin whales were involved in collisions most frequently (31 in the United States and 16 in France). From 2005 to 2009, the minimum annual rate of mortality for the North Atlantic stock from anthropogenic causes was approximately 2.6 per year, while from 2008 to 2012, this number has increased to 3.35 (Waring et al. 2011; 2015). Increase in ambient noise has also impacted fin whales, for whales in the Mediterranean have demonstrated at least two different avoidance strategies after being disturbed by tracking vessels (Jahoda et al. 2003). The best abundance estimate available for the western North Atlantic fin whale stock is 1,618 (Waring et al. 2015).

Fin whales are present in the Rhode Island waters during all four seasons. In spring, summer, and fall, the main center of their distribution is in the Great South Channel area to the east of Cape Cod, which is a well-known feeding ground (Kenney and Winn 1986). Winter is the season of lowest overall abundance, but they do not depart the area entirely. Fin whales are the most common large whale encountered in continental shelf waters south of New England and into the Gulf of Maine. They are the whales most often encountered by local whale-watching operations in most years and are likely to occur in the Project Area. The species is listed as Endangered due to the depletion of its population from whaling (Reeves et al. 1998). A recovery plan has been written and is available from the NOAA Fisheries for review (Waring et al. 2010; 2011).

Minke Whale (*Balaenoptera acutorostrata*) – Non-Strategic
Minke whales are among the most widely distributed of all the baleen whales. They occur in the North Atlantic and North Pacific, from tropical to polar waters. Common minke whales range between 20 and 30 ft (6 and 9 m long) (with maximum lengths of 30 to 33 ft [9 to 10 m]) and are the smallest of the North Atlantic baleen whales (Jefferson et al. 1993; Wynne and Schwartz 1999; Kenney and Vigness-Raposa 2009). The primary prey species for minke whales are most likely sand lance, clupeids, gadoids, and mackerel (Kenney and Vigness-Raposa 2009). These whales basically feed below the surface of the water, and calves are usually not seen in adult feeding areas. Minke whales are almost absent from OCS waters off the western Atlantic in winter; however, they are common in the fall and abundant in spring and summer (CeTAP 1982; Kenney and Vigness-Raposa 2009). The most recent estimate for minke whales in the Canadian East Coast stock is 20,741 (Waring et al. 2015). Minke whales have been observed in Rhode Island waters during all four seasons. The relative abundance models created by Kenney and Vigness-Raposa (2009) predicted that minke whales would be common in Rhode Island coastal waters between spring and summer, but not during fall or winter. Some documented sightings occurred within the Rhode Island waters in the fall; however, they were not observed during recent surveys conducted in support of the RI Ocean SAMP (Kenney and Vigness-Raposa 2009).

As is typical of the baleen whales, minke whales are usually seen either alone or in small groups, although large aggregations sometimes occur in feeding areas (Reeves et al. 2002). Minke populations are often segregated by sex, age, or reproductive condition. Known for their curiosity, minke whales often approach boats.

Minke whales are impacted by ship strikes and bycatch from bottom trawls, lobster trap/pot, gillnet, and purse seine fisheries. From 2005 to 2009, the minimum annual rate of mortality for the North Atlantic stock from anthropogenic causes was approximately 5.9 per year, while from 2008 to 2012 this increased to 9.9 per year (Waring et al. 2011; 2015). In addition, hunting for Minke whales continues today, by Norway in the northeastern North Atlantic and by Japan in the North Pacific and Antarctic (Reeves et al. 2002). International trade in the species is currently banned. The best recent abundance estimate for this stock is 8,987 (Waring et al. 2011). Average annual fishery-related mortality and serious injury does not exceed the potential biological removal for this species; therefore, NOAA Fisheries considers this species as "non-strategic" (Waring et al. 2010; 2011; 2015).

4.3 Earless Seals (Phocidae)

Harbor seal (*Phocac vitulina*) – Non-Strategic
Harbor seals are the most abundant seals in eastern United States waters and are commonly found in all nearshore waters of the Atlantic Ocean and adjoining seas above northern Florida; however, their "normal" range is probably only south to New Jersey. While harbor seals occur year-round north of Cape Cod, they only occur during winter migration south of Cape Cod (Rhode Island to New Jersey) (Waring et al. 2007; Kenney and Vigness-Raposa 2009). During the summer, most harbor seals can be found north of New York, within the coastal waters of central and northern Maine, as well as the Bay of Fundy (DoN 2005).

Harbor seals are relatively small pinnipeds, with adults ranging between 1.7 and 1.9 m in length, with females being slightly smaller than males (Jefferson et al. 1993; Wynne and Schwartz 1999; Kenney and Vigness-Raposa 2009).

Harbor seals prey upon small to medium-sized fish, followed by octopus and squid, and lastly by shrimp and crabs (Kenney and Vigness-Raposa 2009). Fish eaten by harbor seals include commercially important species such as mackerel, herring, cod, hake, smelt, shad, sardines, anchovy, capelin, salmon, rockfish, sculpins, sand lance, trout, and flounders (Kenney and Vigness-Raposa 2009). They spend about 85 percent of the day diving, and much of the diving is presumed to be active foraging in the water column or on the seabed. They dive to depths of about 30 to 500 feet (10 to 150 meters), depending on location. Harbor seals forage in a variety of marine habitats, including deep fjords, coastal lagoons and estuaries, and high-energy, rocky coastal areas. They may also forage at the mouths of freshwater rivers and streams, occasionally traveling several hundred miles upstream (Reeves et al. 2002). They haul out on sandy and pebble beaches, intertidal rocks and ledges, and sandbars, and occasionally on ice floes in bays near calving glaciers. Harbor seals are the only marine mammal that reside in Rhode Island waters, including Block Island and Narragansett Bay. Harbor seals are common in all seasons except during the fall, and are known to be found at haul-out sites on Block Island and points along Narragansett Bay (Kenney and Vigness-Raposa 2009). The most important haul-out site is on the edge of New Harbor, approximately 9 mi (14.5 km) from the proposed BIWF Project.

Except for a strong bond between mothers and pups, harbor seals are generally intolerant of close contact with other seals. Nonetheless, they are gregarious, especially during the molting season, which occurs between spring and autumn, depending on geographic location. They may haul out to molt at a tide bar, sandy or cobble beach, or exposed intertidal reef. During this haulout period, they spend most of their time sleeping, scratching, yawning, and scanning for potential predators such as humans, foxes, coyotes, bears, and raptors (Reeves et al. 2002). In late autumn and winter, harbor seals may be at sea continuously for several weeks or more, presumably feeding to recover body mass lost during the reproductive and molting seasons and to fatten up for the next breeding season (Reeves et al. 2002).

Historically, these seals have been hunted for several hundred to several thousand years. Harbor seals are still killed legally in Canada, Norway, and the United Kingdom to protect fish farms or local fisheries (Reeves et al. 2002). From 2006 to 2010, the average rate of mortality for the Western North Atlantic harbor seal stock from anthropogenic causes was approximately 337 per year (Waring et al. 2013). Average annual fishery-related mortality and serious injury does not exceed the potential biological removal for this species; therefore, NOAA Fisheries considers this species as "non-strategic" (Waring et al. 2013).

Gray seal (*Halichoerus grypus*) – Non-Strategic

The gray seal occurs in cold temperate to sub-arctic waters in the North Atlantic, and is partitioned into three major populations occurring in eastern Canada, northwestern Europe, and the Baltic Sea (Jefferson et al. 2008; Kenney and Vigness-Raposa 2009). The western North Atlantic stock is considered to be the same population as the one found in eastern Canada, and ranges between New England and Labrador (Waring et al. 2007). As exhibited in harbor seal populations, gray seals occur most often in the waters off of Maine during winter and spring, and spend summer and fall off northern Maine and in Canadian waters (DoN 2005). Gray seals exhibit sexual dimorphism, with adult males reaching 2.3 m long and females reaching 2.0 m (Jefferson et al. 1993; Wynne and Schwartz 1999; Kenney and Vigness-Raposa 2009). The gray seal is primarily found in coastal waters and forages in OCS regions (Lesage and Hammill 2001).

Gray seals are gregarious, gathering to breed, molt, and rest in groups of several hundred or more at island coasts and beaches or on land-fast ice and pack-ice floes. They are thought to be solitary when feeding and telemetry data indicates that some seals may forage seasonally in waters close to colonies, while others may migrate long distances from their breeding areas to feed in pelagic waters between the breeding and molting seasons (Reeves et al. 2002). Gray seals molt in late spring or early summer and may spend several weeks ashore during this time. When feeding, most seals remain within 45 miles (72 km) of their haulout sites. Gray seals feed on numerous fish species and cephalopods (Kenney and Vigness-Raposa 2009). Gray seal scat samples from Muskeget Island, Massachusetts, included species such as sand lance, skates, flounder, silver hake, and gadids (Kenney and Vigness-Raposa 2009).

Gray seals form colonies on rocky island or mainland beaches, though some seals give birth in sea caves or on sea ice, especially in the Baltic Sea. Gray seals prefer haulout and breeding sites that are surrounded by rough seas and riptides where boating is hazardous. Pupping colonies have been identified at Muskegat Island (Nantucket Sound), Monomoy National Wildlife Refuge, and in eastern Maine (Rough 1995). The gray seal colony of Massachusetts has more than 5,600 seals total and there are more than 1,700 individuals in Maine (Waring et al. 2007). This species has been reported with greater frequency in Rhode Island waters in recent years, likely due to a population rebound in southern New England and the mid-Atlantic (Kenney and Vigness-Raposa 2009); however, most gray seals present are juveniles dispersing in the spring. The only consistent haul-out locations within the vicinity of Rhode Island are along the sandy shoals around Monomoy and Nantucket in Massachusetts (Kenney and Vigness-Raposa 2009). According to Kenney and Vigness-Raposa (2009), gray seal occurrence is low in the Rhode Island waters; however, as stated previously, the population for this species has been increasing, therefore increasing the potential for interaction with these species in the Project Area.

The biggest threats to gray seals are entanglements in gillnets or plastic debris (Waring et al. 2004). The total estimated human-caused mortality from 2006 to 2010 to gray seals was approximately 5,253 per year, which includes the removal of nuisance animals in Canada (Waring et al. 2015). Average annual fishery-related mortality and serious injury does not exceed the potential biological removal for this species; therefore, NOAA Fisheries considers this species as "non-strategic" (Waring et al. 2015).

5.0 TYPE OF INCIDENTAL TAKE AUTHORIZATION REQUESTED

DWBI is requesting the authorization for potential non-lethal "taking" of small numbers of marine mammals to allow for incidental harassment resulting from the construction of the BIWF. The request is based upon projected construction activities during the anticipated Project schedule as described in Section 2.1.

The results of the underwater acoustic modeling as depicted in Table 1-3 are consistent with similar offshore construction activities. As evidenced in Table 1-3, none of the proposed Project construction activities will result in TTS or PTS and sound levels associated with Level A harassment will only occur very close to the source (less than 5 m). DP thruster use during cable installation could however result in temporary Level B harassment of marine mammals.

To ensure that the potential for take by Level B harassment is minimized to the maximum extent possible DWBI has committed to the mitigation measures outlined in Sections 11.0, which have been successfully implemented during similar offshore construction activities in the North Atlantic.

5.1 BIWF Cable Installation

As detailed in Section 1.3, the use of a DP vessel thrusters during cable installation would generate underwater noise with sounds exceeding the 120 dB thresholds for Level B harassment continuous sound, respectively. DWBI is requesting the authorization for the incidental take by harassment, of small numbers of marine mammals in Rhode Island Sound pursuant to Section 101(a)(5) of the MMPA and in accordance with 50 CFR § 216 Subpart I, in support of BIWF construction activities. The following nine species are requested to be approved for take by Level B Harassment:

- North Atlantic right whale (*Eubalaena glacialis*)
- Humpback whale (*Megaptera novaeangliae*)
- Fin whale (*Balaenoptera physalus*)
- Minke whale (*B. acutorostrata*)
- Atlantic white-sided dolphin (*Lagenorhynchus acutus*)
- Short beaked common dolphin (*Delphinus delphis*)
- Harbor porpoise (*Phocoena phocoena*)
- Harbor seal (*Phoca vitulina*)
- Gray seal (*Halichoerus grypus*)

6.0 TAKE ESTIMATES FOR MARINE MAMMALS

DWBI seeks authorization for potential "taking" of small numbers of marine mammals under the jurisdiction of the NOAA Fisheries in the proposed region of activity. Species for which authorization is sought include the North Atlantic right, fin, humpback, and minke whales, as well as, common and Atlantic white-sided dolphins, harbor porpoise, and harbor and gray seals. These nine species, described in detail in Section 4.0, have the highest likelihood of occurring, at least occasionally, in the Project Area.

The only anticipated impacts to marine mammals are associated with noise propagation from the use of DP thrusters during jet plowing activities, resulting in short-term displacement of marine mammals from within ensonified zones produced by such a noise source.

6.1 Basis for Estimating Numbers of Marine Mammals that Might be "Taken by Harassment"

Most marine animals can perceive underwater sounds over a broad range of frequencies from about 10 hertz (Hz) to more than 10,000 Hz (10 kilohertz (kHz)). Many of the dolphins and porpoises use even higher frequency sound for echolocation and perceive these high frequency sounds with high acuity. Marine mammals respond to low-frequency sounds with broadband intensities of more than about 120 dB re 1 µPa, or about 10 to 20 dB above natural ambient noise at the same frequencies (Richardson et al. 1991).

Sound is important to marine mammals for communication, individual recognition, predator avoidance, prey capture, orientation, navigation, mate selection, and mother-offspring bonding. Potential effects of anthropogenic sounds to marine mammals can include physical injury (e.g., temporary or permanent loss of hearing sensitivity), behavioral modification (e.g., changes in foraging or habitat-use patterns), and masking (the prevention of marine mammals from hearing important sounds).

Project activities that have the potential to cause harassment as defined by the MMPA includes the noise associated with the use of DP vessel thrusters during cable installation activities (120 dB). DWBI conducted a detailed underwater acoustic modeling assessment to better understand both the level and extent of underwater noise generated by Project activities and their potential to impact marine species. The results of the underwater acoustic modeling assessment are summarized in Section 1.3. The complete Underwater Acoustic Assessment Report is included as Appendix A.

The basis for the take estimate is the number of marine mammals that would be exposed to sound levels in excess of Level B harassment criteria (120 dB continuous). Typically this is determined by multiplying the zone of influence (ZOI) out to the Level B harassment criteria isopleth by local marine mammal density estimates, and then correcting for seasonal use by marine mammals, seasonal duration of noise-generating activities, and estimated duration of individual activities when the maximum noise-generating activities are intermittent or occasional. In the absence of any part of this information, it becomes prudent to take a conservative approach to ensure the potential number of takes is not greatly underestimated.

Acoustic modeling was completed with the widely-used Range Dependent Acoustic Model (RAM) which is based on the U.S. Navy's Standard Split-Step Fourier Parabolic Equation. This modeling analysis method considers range and depth along with a geo-referenced dataset to automatically retrieve the time of year information, bathymetry, and geoacoustic properties (e.g. hard rock, sand, mud) along propagation transects radiating from the sound source. Transects are run along compass points (45°, 90°, 135°, 180°, 225°, 270°, 315°, and 360°) to determine received sound levels at a given location. These values are then summed across frequencies to provide broadband received levels at the MMPA Level A and Level B harassment thresholds as described in Table 1-3. The representative area ensonified to the MMPA Level B threshold for DP vessel thruster use during cable installation was used to estimate take. The maximum critical distances to the MMPA thresholds were used to conservatively estimate how many marine mammals would receive a specified amount of sound energy in a given time period and to support the development of monitoring and/or mitigation programs (see Sections 11.0).

For DP thruster use during cable installation, the ensonified area at the 120-dB isopleth was modeled at three representative water depths (10 m, 20 m, and 40 m) associated with the Inter-Array Cable and Export Cable routes. Because the vessel will be continuously moving along the cable routes during installation activities, the ZOI for DP thrusters has been conservatively estimated to be approximately 9.7 mi^2 (25.1 km^2). This ZOI also represents the average ensonified area across the three representative water depths associated with the cable routes. See Appendix A, Figures A-5 through A-7 for a depiction of maximum ZOIs at each water depth and power level. As shown in Table 1-3, DP thrusters will not produce sound levels at 180 dB at any appreciable distance from the vessel.

6.2 Estimate of Numbers of Marine Mammals that Might be "Taken by Harassment"

As described in Section 6.1, the incidental take analysis was based on the number of marine mammals that would be exposed to sound levels in excess of Level B harassment criteria (120 dB continuous) for DP vessel thrusters during cable installation. Table 1.3 shows the maximum calculated distances in meters to each isopleth. Section 6.1 provides the maximum potential ZOIs for each activity based on site specific acoustic modeling under a typical cable installation scenario. Take estimates were calculated using these estimates to assess the potential effects on the nine species of marine mammals identified in Section 5.0 as having the highest likelihood of occurring, at least occasionally, in the general Project Area. The data used as the basis for estimating species density for the Project Area is sightings per unit effort (SPUE) taken from Kenney and Vigness-Raposa (2009). SPUE (or, the relative abundance of species) is derived by using a measure of survey effort and number of individual cetaceans sighted. SPUE allows for comparison between discrete units of time (i.e., seasons) and space within a project area (Shoop and Kenney, 1992). SPUE calculated by Kenney and Vigness-Raposa (2009) was derived from a number of sources including: 1) North Atlantic Right Whale Consortium database (NARWC); 2) CeTAP (CeTAP, 1982); 3) sightings data from the Coastal Research and Education Society of Long Island, Inc. (CRESLI) and Okeanos Ocean Research Foundation; 4) the Northeast Regional Stranding (NERS) network (marine mammals); and 5) the NOAA Fisheries Sampling Branch (Woods Hole, MA).

The Northeast Navy OPAREA Density Estimates (DoN 2007) were also used in support for estimating take for seals, which represents the only available comprehensive data for seal abundance. However, abundance estimates for the Southern New England area (including Rhode Island waters) includes breeding populations on Cape Cod, and therefore using this dataset alone will result in a substantial over-estimate of take in the Project Area. However based on reports conducted by Kenney and Vigness-Raposa (2009), Schroeder (2000) and Ronald and Gots (2003), harbor seal abundance off the coast of Rhode Island is likely to be approximately 20 percent of the total abundance for southern New England. In addition, because the seasonality of, and habitat use by, gray seals off the coast of Rhode Island roughly overlaps with harbor seals, the same abundance assumption of 20 percent of the southern New England population of gray seals can be applied when estimating abundance off the coast of Rhode Island. Per this data and consultations with NOAA (Michelle Magliocca, Personal Communication, January 4, 2013) take due to Level B harassment for harbor seals and gray seals have been calculated based on 20 percent of the Northeast Navy OPAREA Density Estimates.

Estimates of Take are computed according to the following formula:

$$\textit{Estimated Take} = D \times ZOI \times (1.5) \times (d)$$

Where:

D = average highest species density (number per 100 km^2)

ZOI = maximum ensonified area to MMPA thresholds for impulse (160 dB) or continuous (120dB) noise

1.5 = Correction factor to account for marine mammals that may be underwater

d = number of days

Calculations of estimate take are detailed in the following section. Take estimates for DP thruster use during jet plowing activities by species are provided in Table 6-1.

Due to the spatial distribution and transient nature of marine mammal species identified; the relatively short duration of the activities and the time of year DWBI proposes to conduct construction activities; and the implementation of the mitigation measures as described in Section 11.0, construction activities are not likely result in serious injury or death.

6.2.1 Estimate of Potential Takes by Harassment

Estimates of DP vessel thruster use during cable laying activities have been based on a maximum ZOI of 9.7 mi^2 (25.1 km^2). As detailed in Section 6.1, this ZOI represents the average ensonified area across the three representative water depths within the Project Area (10 m, 20 m, and 40 m). Cable installation is expected to require up to 28 between the months of April and October. To be conservative, take calculations were based on the highest seasonal species density when cable installation may occur (see Table 6-1). The resulting take estimates (rounded to the nearest whole number) based upon these conservative assumptions for North Atlantic right, humpback, fin, and minke whales, as well as, common and Atlantic white-sided dolphins, harbor porpoise, and harbor and gray seals are presented in Table 6-1. These numbers are based on 28 days and represent a maximum of 0.215, 0.017, 1.42, 0.024, 0.072, 0.162, 0.010, 0.028, and 0.009 percent of populations for these species, respectively. These percentages are the upper boundary of the animal population that could be affected. Mitigation and monitoring of potential take during DP vessel thruster use is detailed in Section 11.0.

Table 6-1 Marine Mammal Density and Estimated Level B Harassment Take Numbers during Inter-Array Cable and Export Cable Installation.

Species	Density Spring (No./100 km²)	Density Summer (No./100 km²)	Density Fall (No./100 km²)	Maximum Density (No./100 km²)	Requested Take Authorization (No.)
North Atlantic Right Whale	0.06	0.03	0.07	**0.07**	1
Humpback Whale	0.11	0.00	0.05	**0.11**	2
Fin Whale	0.62	2.15	0.14	**2.15**	23
Minke Whale	0.12	0.14	0.44	**0.44**	5
Common Dolphins	2.59	2.28	8.21	**8.21**	87
Atlantic White-sided Dolphin	1.23	0.00	7.46	**7.46**	79
Harbor Porpoise	0.74	0.33	0.23	**0.74**	8
Harbor Seal [a/]	9.74	0.00	9.74	**9.74**	21
Gray Seal [a/]	14.16	14.16	14.16	**14.16**	30

a/ Density values were derived using 20 percent of the number estimated from DoN (2007) density values.

7.0 ANTICIPATED IMPACTS OF THE ACTIVITY

Consideration of negligible impact is required for the NOAA Fisheries to authorize the incidental take of marine mammals. In 50 CFR § 216.103, the NOAA Fisheries defines negligible impact to be "an impact resulting from a specified activity that cannot be reasonably expected to, and is not reasonably likely to, adversely affect the species or stocks [of marine mammals] through effects on annual rates of recruitment or survival." Based upon best available data regarding the marine mammal species (including density, status, and distribution) that are likely to occur in the Project Area, DWBI concludes that exposure to marine mammal species and stocks during construction of the BIWF would result in short-term minimal effects and would not likely affect the overall annual recruitment or survival for the following reasons:

- As detailed in Section 1.3 and Appendix A, potential acoustic exposures from Project construction activities are within the non-injurious behavioral effects zone (Level B harassment);
- The potential for take as estimated in Section 6.2 represents a conservative estimates of harassment based upon typical construction scenarios without taking into consideration the effects of standard mitigation and monitoring measures; and
- The protective measures as described in Section 11.0 are designed to minimize the potential for interactions with and exposure to marine mammals.

Marine mammals are mobile and are expected to quickly leave an area when noise-producing construction activities are initiated. While Project activities may disturb more than one individual, short-term construction activities are not expected to result in population-level effects and individuals would likely return to normal behavioral patterns after noise producing activities have ceased or after the animal has left the construction area.

8.0 ANTICIPATED IMPACTS ON SUBSISTENCE USES

There are no traditional subsistence hunting areas in the Project Area.

9.0 ANTICIPATED IMPACTS ON HABITAT

The construction of the BIWF Inter-Array and Export Cable involves activities that will disturb the seafloor, which will affect benthic and finfish communities, and in turn could result in the loss or alteration of foraging resources for marine mammals. Impacts to these resources from Project construction activities will include:

- Installation of the Inter-Array Cable and Export Cable via jet plow;
- Additional cable armoring, as required; and
- Anchoring of construction support of vessels.

Installation of the Inter-Array Cable and Export Cable will result in the temporary disturbance of a maximum of 3.7 and 11.3 acres of seafloor, respectively. These installation activities will also result in temporary and localized increases in total suspended solid (TSS) and turbidity in the water column that will be transported and deposited in areas adjacent to construction activities. The Inter-Array Cable and Export Cable may also require additional protective armoring in areas where the burial depth achieved is less than 4 ft (1.2 m). DWBI expects that additional protection would be required at a maximum of 1 percent of the entire submarine cable. Bags of sand and/or cement will also be placed on the seafloor secure the Inter-Array Cable between the exit point and subsea burial point at the base of each the jacket foundation. The resulting maximum conversion of soft substrate to hard substrate from these activities will be up to 0.4 acres (0.2 hectare) along the cable routes. During the installation of additional protective armoring as necessary along the cable routes where burial depth is less than 4 ft (1.2 m), anchors and anchor chains will result in approximately 1.8 acres (0.7 hectares) of temporary bottom impact during each anchoring event including anchors and anchor chains.

Jet-plowing and impacts from construction vessel anchor placement and/or sweep will cause either the displacement or loss of benthic and finfish resources in the immediate areas of disturbance. This is likely to result in a temporary loss of forage items and a temporary reduction in the amount of benthic habitat available for foraging marine mammals that are dependent on these resources. However, the amount of habitat affected represents a very small percentage of the available foraging habitat in the Project Area. It is likely that marine mammals may temporarily shift their foraging efforts to other areas within or around the Project Area. While this would affect the movements of individual marine mammals, it is likely to be temporary and is not likely to affect marine mammal nourishment or result in any injury or mortality.

10.0 ANTICIPATED EFFECTS OF HABITAT IMPACTS ON MARINE MAMMALS

As stated in Section 9.0, given the minimal suspension and deposition of sediments from cable installation, the fact that the cable will be buried below the sea floor, and the low abundance of marine mammals in the Project Area (see Table 6-1), it is reasonable to conclude that there will be no effects to marine mammals from loss or modification of habitat.

11.0 MITIGATION MEASURES

DWBI commits to engaging in on-going consultations with NOAA Fisheries throughout the remainder of the BIWF construction. DWBI voluntarily commits to a comprehensive set of mitigation measures during construction of the BIWF. The mitigation procedures outlined in this section are based on protocols and procedures that have been successfully implemented in similar offshore construction projects and previously approved by NOAA Fisheries. These mitigation measures have also already been reviewed and approved by NOAA Fisheries in the BIWF IHA issued on September 3, 2014 and amended on June 11, 2015 as well as the BITS IHA issued on August 8, 2013 and amended on November 3, 2015.

As previously committed to, all construction equipment will also, to the extent possible, comply with applicable equipment noise standards of the U.S. Environmental Protection Agency (EPA).

Exclusion and Monitoring Zones

Exclusion zones (defined as the Level A harassment zone of influence [ZOI] out to the 180 dB isopleth) and monitoring zones (defined as the Level B harassment ZOI out to the 120 dB for continuous noise) are typically established to minimize impacts to marine mammals and sea turtles. However, noise analysis has indicated that DP vessel thruster use will not produce sound levels at 180 dB at any appreciable distance. Therefore, injury to marine mammals and sea turtles is not expected and no Level A harassment exclusion zone is proposed.

Consultation with NOAA has indicated that the monitoring zones established out to the 120 dB isopleth for continuous noise will result in zones too large to effectively monitor (up to 4.75 km; see Table 1-3). Therefore, based on precedent set by the U.S. Department of the Navy and recent European legislation regarding compliance thresholds for underwater construction noise (DoN, 2012; OSPAR, 2008) and the previous IHA's issued to DWBI, and sea2shore: A Renewable Energy Link (sea2shore), formerly known as the Block Island Transmission System, DWBI will establish a monitoring zone of 5 m (approximately 0.003 nm) from the DP vessel. This zone is equivalent to the size of the predicted 160 dB isopleth for DP vessel thruster use. This monitoring zone represents the minimum area of coverage for Level B harassment. All marine mammal sightings which are visually feasible, including those beyond the 160 dB isopleth, will be recorded and potential takes will be noted.

Protected Species Observers

Visual observation of the monitoring zone established for DP vessel operation during cable installation will be performed by qualified and NOAA Fisheries approved protected species observers (PSOs). Observer qualifications will include direct field experience on a marine mammal/sea turtle observation vessel and/or aerial surveys in the Atlantic Ocean/Gulf of Mexico. It is anticipated a minimum of two PSOs will be stationed aboard the cable lay vessel. Each PSO will monitor 360 degrees of the field of vision. PSOs stationed on the DP vessel will begin observation of the monitoring zone as the vessel initially leaves the dock. Observations of the monitoring zone will continue throughout the cable installation and will end after the DP vessel has returned to dock.

PSOs, using binoculars, will estimate distances to marine mammals and sea turtles either visually, using laser range finders, or by using reticled binoculars during daylight hours. During night operations, night-vision binoculars will be used. If vantage points higher than 25 ft (7.6 m) are available, distances can be measured using inclinometers. Position data will be recorded using hand-held or vessel global positioning system (GPS) units for each sighting, vessel position change, and any environmental change.

Each PSO stationed on the cable lay vessel will scan the surrounding area for visual indication of marine mammal and sea turtle presence that may enter the zone. Observations will take place from the highest available vantage point on the cable lay vessel. General 360-degree scanning will occur during the monitoring periods, and target scanning by the PSO will occur when alerted of a marine mammal or sea turtle presence.

Data on all observations will be recorded based on standard PSO collection requirements. This will include dates and locations of construction operations; time of observation, location and weather; details of marine mammal and sea turtle sightings (e.g., species, age classification [if known], numbers, behavior); and details of any observed "taking" (behavioral disturbances or injury/mortality). In addition, prior to initiation of construction work, all crew members on barges, tugs and support vessels, will undergo environmental training, a component of which will focus on the procedures for sighting and protection of marine mammals and sea turtles. A briefing will also be conducted between the construction supervisors and crews, the PSOs, and DWBI. The purpose of the briefing will be to establish responsibilities of each party, define the chains of command, discuss communication procedures, provide an overview of monitoring purposes, and review operational procedures. The DWBI Construction Compliance Manager (or other authorized individual) will have the authority to stop or delay construction activities, if deemed necessary. New personnel will be briefed as they join the work in progress.

Ramp-up/Soft-Start Procedures

The DP vessel thrusters will be engaged from the time the vessel leaves the dock. Therefore, there is no opportunity to engage in a ramp up procedure.

Shut-Down Procedures

During cable installation a constant tension must be maintained to ensure the integrity of the cable. Any significant stoppage in vessel maneuverability during jet plow activities has the potential to result in significant damage to the cable. Therefore, during cable lay if marine mammals enter or approach the established 160 dB isopleth monitoring zone, DWBI proposes to reduce DP thruster to the maximum extent possible, except under circumstances when reducing DP thruster use would compromise safety (both human health and environmental) and/or the integrity of the Project. Reducing thruster energy will effectively reduce the potential for exposure of marine mammals and sea turtles to sound energy. After decreasing thruster energy, PSOs will continue to monitor marine mammal and/or sea turtle behavior and determine if the animal(s) is moving towards or away from the established monitoring zone. If the animal(s) continues to move towards the sound source then DP thruster use would remain at the reduced level. Normal thruster use will resume when PSOs report that marine mammals and/or sea turtles have moved away from and remained clear of the monitoring zone for a minimum of 30 minutes since last the sighting.

Time of Day Restrictions

Cable installation will be conducted 24 hours per day. Night vision equipment will be used by PSOs to monitor the DP thruster monitoring zone.

12.0 ARCTIC PLAN OF COOPERATION

Potential impacts to species or stocks of marine mammals will be limited to individuals of marine mammal species located of the Northeast Region of the United States, and will not affect Arctic marine mammals. Given that the Project is not located in Arctic waters, the activities associated with the BIWF will not have an adverse effect on the availability of marine mammals for subsistence uses allowable under the MMPA.

13.0 MONITORING AND REPORTING

13.1 Monitoring

Field verification of the preliminary 5-m (approximately 0.003-nm) radius monitoring zone associated with DP vessel thruster use will be conducted to determine whether the proposed preliminary zone is adequate to minimize impacts to marine mammals and sea turtles. Field verification of the during cable installation will be performed using acoustic measurements from two reference locations at two water depths (a depth at mid-water and a depth at approximately 1 m above the seafloor). As necessary, the monitoring zone will be modified to ensure adequate protection to marine mammals and sea turtles.

13.2 Reporting

DWBI will provide the following reports as necessary during construction activities:

- DWBI will contact USACE and NOAA Fisheries within 24-hours of the commencement of construction activities and again within 24 hours of the completion of the activity.

- The USACE and NOAA Fisheries should be notified within 24 hours whenever a monitoring zone is re-established by DWBI. After any re-establishment of the monitoring zone, DWBI will provide a report to the USACE and NOAA Fisheries detailing the field-verification measurements within 7 days. This includes information, such as: a detailed account of the levels, durations, and spectral characteristics of DP thruster use, and the peak, RMS, and energy levels of the sound pulses and their durations as a function of distance, water depth, and tidal cycle. The USACE and NOAA Fisheries will be notified within 24 hours whenever any new monitoring zone is implemented by DWBI.
- Any observed significant behavioral reactions (e.g., animals departing the area) or injury or mortality to any marine mammals or sea turtles must be reported to USACE and NOAA Fisheries within 24 hours of observation.
- Within 120 days after completion of the construction activities, a final technical report will be provided to USACE, and NOAA Fisheries that fully documents the methods and monitoring protocols, summarizes the data recorded during monitoring, estimates the number of listed marine mammals and sea turtles that may have been taken during construction activities, and provides an interpretation of the results and effectiveness of all monitoring tasks.

14.0 SUGGESTED MEANS OF COORDINATION

All marine mammal data collected by DWBI during cable installation activities will be provided to USACE, NOAA Fisheries, and other interested government agencies, and be made available upon request to educational institutions and environmental groups. These organizations could use the data collected during this period to study ways to reduce incidental taking and evaluate its effects.

15.0 LIST OF PREPARERS

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Appendix A

Underwater Acoustic Modeling Report

Block Island Wind Farm
and
Block Island Transmission System
Underwater Acoustic Report, Revision 1

Original submittal date: May 2012

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ACRONYMS AND ABBREVIATIONS

µPa	micro Pascal
AcTUP	Acoustic Toolbox User Interface Post processor
AC	alternating current
APL	Applied Physics Laboratory
BITS	Block Island Transmission System
BIWF	Block Island Wind Farm
BOEM	Bureau of Ocean Energy Management
C_{water}	speed of sound in water
$C_{sediment}$	speed of sound in sediment
CRM	coastal relief model
CRMC	Rhode Island Coastal Resources Management Council
dB	decibel
dB/km	decibel per kilometer
dBL	linear decibels
Deepwater Wind	Deepwater Wind Block Island, LLC and Deepwater Wind Block Island Transmission, LLC
DP	dynamic position
ER	September 2012 Deepwater Wind Environmental Report
Export Cable	A 34.5-kilovolt (kV) transmission cable from the northernmost WTG to an interconnection point on Block Island
f_c	cutoff frequency
GDEM	Generalized Digital Environmental Model
GEODAS	Geophysical Data System
h	water depth in the direction of sound propagation
HDD	horizontal directional drilling
HP	horsepower
Hz	hertz
Inter-Array Cable	34.5-kilovolt (kV) submarine cable interconnecting the WTGs
kHz	kiloHertz
KJ	kilojoule
km	kilometer(s)
kN	kilonewton
kV	kilovolt
L_n	statistical sound level
m	meter
m^3	cubic meter
mi	mile(s)
m/s	meters per second

MMPA	Marine Mammal Protection Act
MW	megawatt
NGDC	National Geophysical Data Center
NOAA	National Oceanic and Atmospheric Administration
NOAA Fisheries	National Oceanic and Atmospheric Administration, National Marine Fisheries Service
NSR	noise sensitive receptors
PE	parabolic equation
Project	BIWF and BITS, together
Project Area	construction and operation footprint of the BIWF and BITS facilities
psu	practical salinity units
pW/m^2	picowatt per square meter
RAM	Range Dependent Acoustic Model
RI Ocean SAMP	Rhode Island Ocean Special Area Management Plan
RMS	root mean square
SEL	sound exposure level
SSP	sound speed profile
SPL	sound pressure level
TL	transmission loss
USACE	U.S. Army Corps of Engineers
WTG	wind turbine generator

1.0 INTRODUCTION

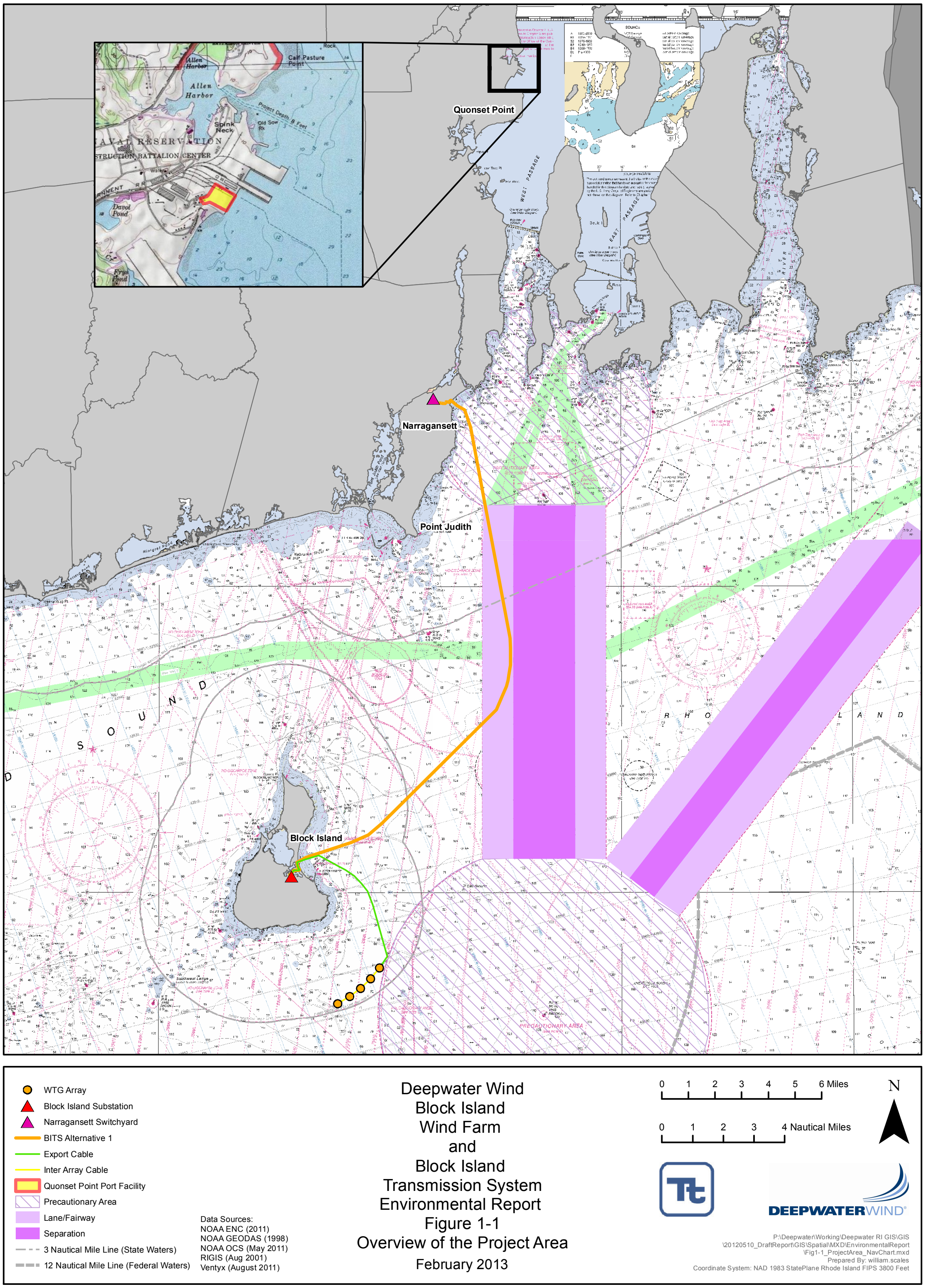
Deepwater Wind Block Island, LLC, a wholly owned indirect subsidiary of Deepwater Wind Holdings, LLC, proposes to develop the Block Island Wind Farm (BIWF), a 30 megawatt (MW) offshore wind farm located approximately 3 miles (mi) (4.8 kilometers [km]) southeast of Block Island, Rhode Island. The BIWF will consist of five, 6-MW wind turbine generators (WTGs), a submarine cable interconnecting the WTGs (Inter-Array Cable), and a 34.5-kilovolt (kV) transmission cable from the northernmost WTG to an interconnection point on Block Island (Export Cable). In connection with the BIWF, Deepwater Wind Block Island Transmission, LLC, also a wholly owned indirect subsidiary of Deepwater Wind Holdings, LLC, proposes to develop the Block Island Transmission System (BITS), a 34.5-kV alternating current (AC) bi-directional submarine transmission cable that will run up to approximately 25.9 mi (41.7 km) from Block Island to the Rhode Island mainland. For the purposes of this analysis, the two Deepwater Wind Holdings, LLC corporate entities associated with the development of the BIWF and BITS are collectively referred to as “Deepwater Wind.” Likewise, the BIWF and BITS are collectively referred to as “the Project.” The “Project Area” refers to the footprint of the BIWF and BITS facilities. Figure 1-1 provides an overview of the Project Area.

Noise will be generated during construction and operation of the BIWF and during construction of the BITS. Both in-air and underwater noise impacts are considered as a part of the permitting process. The evaluation of noise impacts is typically most critical at noise sensitive receptors (NSRs), which for the purposes of the in-air environment are structures such as residences, hospitals, schools, etc. and in the underwater environment are marine mammals, sea turtles, and fish. The following acoustic assessment deals specifically with potential noise impacts that may occur as a result of the Project within the underwater environment. Primary noise-generating activities have been identified during construction such as pile driving during WTG foundation installation, vibratory pile driving during cofferdam installations, and vessel activity related to cable laying. Underwater noise associated with WTG operation is also qualitatively discussed. The overall objectives of this study were to: (1) estimate site-specific sound propagation characteristics incorporating geoacoustic properties of the underlying substrates and bathymetric effects; (2) computer simulate Project sound levels using sound propagation modeling codes; and (3) provide comparative analyses to biological significance thresholds and evaluate the feasibility of the Project to be in compliance with applicable noise requirements.

Deepwater Wind is currently considering two options for bringing the BIWF and BITS marine cables ashore. These landing alternatives include either (1) conducting a long-distance horizontal directional drill (HDD) from shore to a temporary offshore cofferdam; or (2) conducting a short-distance HDD to an excavated trench located at mean high water from which a jet plow would be launched directly from the beach. The primary difference between these two methodologies is that the short-distance HDD will not require an offshore cofferdam, which requires the use of vibratory pile driving for its installation. If a short-distance HDD is used, there will be no offshore cofferdam, and thus, no noise impact associated with the installation of the offshore cofferdam.

The expected spatial distribution of underwater noise levels has been determined for multiple scenarios, in cooperation with the Project engineering team to ensure an accurate representation of the activities that will occur during construction and operation of the proposed Project. Modeling results of the underwater acoustic analysis are presented as plots of distances along single transects for each modeled Project scenario. These distances correspond to National Oceanic and Atmospheric Administration (NOAA), National Marine Fisheries Service (NOAA Fisheries) marine species harassment criteria thresholds.

Figure 1-1 Overview of Project Area



Information provided is intended to form the basis for the assessment of potential sound impacts during Project construction and operation on marine species such as fish, sea turtle, and marine mammals within the Project Area. After potential sound impacts have been assessed, mitigation strategies can be developed to minimize these impacts, if required.

The data and analysis provided in this report have been updated from the original analysis submitted in the September 2012 Deepwater Wind Environmental Report (ER) in direct response to comments made by the NOAA Fisheries during the U.S. Army Corps of Engineers (USACE) public comment period (October 2, 2012 through February 10, 2013). These comments include a specific request to adjust the proposed Project construction schedule to avoid impact pile driving during the North Atlantic Right Whale migration period between the months of November through April (letter to USACE dated November 13, 2012); and to further refine the Project base-case construction assumption to more accurately reflect actual anticipated activities and equipment versus worst-case as originally analyzed in the ER (Julie Crocker, Personal Communication, November 8, 2012).

1.1 Underwater Acoustic Concepts and Terminology

The sound level estimates from this modeling study are expressed in terms of several metrics to allow for interpretation relative to potential biological impacts on marine life. Interpretation of such impacts is provided under separate cover. For purposes of document brevity, it is assumed the reader is familiar with basic acoustical terms, descriptors, and concepts that should help frame the discussion of acoustics in this technical report. The majority of the information in the following sections is to provide insight into how data and modeling results have been presented.

Reference Levels

Sound levels are reported on a logarithmic scale expressed in units of decibels (dB) and are reported in terms of linear (or unweighted) decibels. Linear decibels are referred to as dBL in this report. A dB is defined as the ratio between a measured value and a reference value of 1 micro-Pascal (μPa). A logarithmic scale is formed by taking 20 times the logarithm (base 10) of the ratio of two pressures: the measured sound pressure divided by a reference sound pressure. Evaluating sound propagation in the underwater environment is more complex than in an in-air environment (see Appendix N-1 In-Air Acoustic Report). The reference sound for underwater sound pressure is 1 μPa; however, in-air sound uses a reference of 20 μPa. Due to the difference in acoustic impedance, a sound wave that has the same intensity in air and in water will in water have a pressure that is 60 times larger than in air, with a displacement amplitude that will be 60 times less. Assuming pressure is maintained as a constant, the displacement amplitude in water will be 3580 times less than in air. To help demonstrate this relationship, Table 1-1 provides the corresponding values of sound pressure in air and in water having the same intensities at a frequency of 1 kiloHertz (kHz) as it relates to human-perceived loudness. This comparison does not account for the frequency dependent hearing capabilities of various species (e.g., marine species) or individual hearing response mechanisms.

Table 1-1 Sound Pressure Levels and Comparison to Relative Human Loudness Thresholds

Pressure in Air re 20 µPa/Hz	Pressure in Water re 1µPa/Hz	Relative Loudness (human perception of different reference sound pressure levels in air)[1]
0	62	Threshold of Hearing
58	120	Potentially Audible Depending on the Existing Acoustic Environment
120	182	Uncomfortably Loud
140	202	Threshold of Pain
160	222	Threshold of Direct Damage
Source: Kinsler and Frey 1962		

Statistical Levels

Statistical levels describe the temporal variation in sound levels. Underwater sound pressure levels may change from moment to moment; some are sharp impulses lasting one second or less, while others may rise and fall over much longer periods of time. Statistical levels provide a percentile time history of the time-varying sound levels. The statistical sound levels (L_n) provide the sound level exceeded for that percentage of time over the given measurement period. An L_{10} level is often referred to as the intrusive noise level and is the sound level that is exceeded for 10 percent of the time during a specified measurement period. The L_{90} level is the sound level that is exceeded for 90 percent of the time during the measurement time period, or the quietest 10 percent of a given time period. Often referred to as the residual sound level, L_{90} can be an indicator of the potential for acute perceptibility of a new sound source as it will not tend to include sound from transient events (such vessel watercraft passbys), unless they occurred for the entire measurement duration. Statistical levels can be specified as broadband "single number" values and also frequency dependent numbers (i.e., in one-third octave bands).

Underwater sounds are classified according to whether they are transient or continuous. Transient sounds are of short duration and occur singly, irregularly, or as a part of a repeating pattern. For instance, an explosion represents a single transient event, whereas the periodic pulses from a ship's sonar are patterned transients. Broadband short duration transients are called pulses. Continuous sounds, which occur without pauses, may be further classified as periodic, such as the sound from rotating machinery or pumps, or aperiodic, such as the sound of a ship transiting. Shipping is considered a short-term continuous sound. These sounds normally increase in level with higher engine loads or as vessels approach an observation location and then diminish as they move away. Fixed-location continuous sounds are associated with an operational offshore WTG. The use of a vibratory hammer for the construction of the cofferdam will produce sounds that are of a continuous nature, although they will be intermittent and of relatively short duration. The intensity of continuous noise is generally given in terms of the root mean square (RMS) sound pressure level (SPL). The RMS SPL (also referred to as the time-averaged level) is calculated by taking the square root of the average of the square of the pressure waveform over the duration of the time period. The RMS is also known as the quadratic mean and is a statistical measure of the magnitude of a varying quantity. It is especially useful when variates, pressures in the underwater environment, are positive and negative such as what is exhibited in a sinusoid. Exposure to this sound level over the

[1] Kinsler and Frey: Fundamentals of Acoustics, 2nd edition, John Wiley & Sons, 1962.

measurement period would result in the same noise dose as being exposed to the actual varying sound levels over that same period. Given a measurement of the time varying sound pressure p(t) from a given noise source at some location, the RMS SPL (L_P) is computed according to the following formula:

$$L_P = 10log_{10}\frac{1}{T}\int_T p(t)^2 dt/P_{ref}^2$$

Where T is the measurement period.

Pulses are defined as brief, broadband, atonal, transients. These sounds are all characterized by a relatively rapid rise from ambient pressure to a maximal pressure value followed by a decay period that may include a period of diminishing, oscillating maximal and minimal pressures. The rapid rise-time characteristic of these sounds ensures that they are also broadband in nature, with the higher-frequency components being related to the rapidity of the rise time. Pile driving using an impact hammer during construction of the jacket foundations is an example of underwater noise that is characterized as pulsed sound. In addition, the Project may require the use of an impact hammer, as a contingency, to drive the sheets for the cofferdam construction to seat the piles into the last few meters of the seafloor. Impulse sounds may be characterized by L_{peak}, which is the maximum instantaneous sound pressure level attained by an impulse, p(t):

$$L_{peak} = 20log_{10}(max|p(t)|)$$

Where p(t) is the instantaneous pulse pressure as a function of time, measured over the pulse duration $0 \leq t \leq T$. This metric is very commonly quoted for impulsive sounds but does not take into account the pulse duration or bandwidth of a signal. For pulsed noise, the RMS sound pressure level may be measured over the pulse duration according to the following equation:

$$L_P = 10log_{10}\left(\frac{1}{T}\int_T p^2(t)dt/P_{ref}^2\right)$$

The time interval, T, above, is most often taken to be the “90 percent energy pulse duration” rather than a fixed time window when computing pile driving safety radii. The 90 percent energy pulse duration is computed for each seismic shot as the window containing 90 percent of the pulse energy, and RMS SPLs computed in this way are commonly referred to as 90 percent RMS SPLs. In addition, because the window length is used as a divisor, pulses that are more spread out in time have a lower RMS SPL for the same total acoustic energy.

The final sound metric is referred to in the following report is the sound exposure level (SEL). The SEL is the dB level of the cumulative sum-of-square pressures over the duration of a sound (e.g., 1 dB μPa^2-s) for sustained nonpulse sounds where the exposure is of a constant nature. However, this measure is also extremely useful for pulses and transient nonpulse sounds because it enables sounds of differing duration to be characterized in terms of total energy for purposes of assessing exposure risk. The SEL metric also enables integrating sound energy for exposure from multiple sources. The SEL for a single pulse is computed using the equation below.

$$L_{SEL} = 10log_{10}\left(\int_T p^2(t)dt/P_{ref}^2\right)$$

Unless otherwise stated in this report, the sound exposure levels from a pulsed noise source (e.g., impact hammer pile driving) are presented as single pulses.

Spectral Levels

Acoustic modeling results are presented in one-third octave band center frequencies. The one-third octave spectra of the single event sound pressure level were evaluated in the range of 10 hertz (Hz) to 5 kHz. One-third octaves are a series of electronic filters used to separate sound into discrete frequency bands, making it possible to know how sound energy is distributed as a function of frequency. Corresponding broadband dBL sound levels sum the acoustic energy across all frequencies. These analyses quantitatively describe the frequency (Hz) dependent sound environment for specific events or activities. The advantage of one-third octave band modeling is that it can resolve the frequency dependent propagation characteristics of a particular environment and can be summed to efficiently compute the overall broadband sound pressure level for any given receiver position within the water column.

Absorption

Absorption in the underwater environment involves a process of conversion of acoustic energy into heat and thereby represents a true loss of acoustic energy to the water. The primary causes of absorption have been attributed to several processes, including viscosity, thermal conductivity, and chemical reactions involving ions in the seawater. The viscosity of the medium causes sound energy to be converted into heat by internal friction. Some sound energy is converted into heat because sound waves alternately raise and lower the temperatures. Suspended particles are set to oscillating by the sound waves and in this process some of the sound energy is dissipated in the form of heat. This is especially the case if the particles are air bubbles. While each of these factors offers its own unique contribution to the total absorption loss, all of them are caused by the repeated pressure fluctuations in the medium as the sound waves are propagated. In these processes, the area over which the signal is spread remains the same, but the energy in the signal, and therefore the intensity, is decreased.

The absorption of sound energy by water contributes to the transmission loss (TL) linearly with distance and is given by an attenuation coefficient in units of dB per kilometer (dB/km). This absorption coefficient is computed from empirical equations and increases with the square of frequency. For example, for typical open-ocean values (temperature of 10°Celsius, pH of 8.0, and a salinity of 35 practical salinity units [psu]), the equations presented by Francois and Garrison (1982a, b) yield the following values for seawater absorption: 0.001 dB/km at 100 Hz, 0.06 dB/km at 1 kHz, 0.96 dB/km at 10 kHz, and 33.6 dB/km at 100 kHz. Thus, low frequencies are favored for long-range propagation.

Spatial Effects and Spreading

Spreading loss is simply the attenuation of acoustic energy over a larger area so that the acoustic energy decreases as the wave propagates away from a source. Three fundamental equations can be used to describe spreading losses. These equations present a simplified approach to calculate TL between source and receiver. For the Project a more detailed modeling analysis was conducted using site-specific inputs for sound sources, bathymetry, geoacoustic properties, and sound speed profiles. The first equation used for noise modeling covers TL for short ranges near the source, where sound energy spreads outward unimpeded by interactions at the sea surface or sea floor until the entire channel depth is insonified. The following equation is used when r, the horizontal separation distance between sound source and receiver, is up to 1 times H, which is conservatively assumed as the average water depth for conducting screening-level calculations. The equation also includes a range and frequency dependent absorption term, α.

$$TL = 20\log r + \alpha r$$

The intermediate (or transition zone) is defined as H ≤ r ≤ 8H where modified cylindrical spreading occurs accompanied by mode stripping effects (Richardson et al. 1995). The TL equation representing this intermediate range is given below:

$$TL = 15\log r + \alpha r$$

For underwater transmission in shallow water where the water depth is greater than five-times the sound wavelength, the 15 log r spreading loss factor in the above equation may extend beyond the range of 8H. Long range TL occurs where r > 8H. Due to the boundaries of the sea surface and sea floor, sound energy is not able to propagate uniformly in all directions from a source indefinitely; therefore, long range TL is represented as cylindrical spreading, limited by the channel boundaries. Cylindrical spreading propagation is applied using the equation given below:

$$TL = 10\log r + \alpha r$$

These equations are based on free-field conditions that assume uniform sound spreading in an infinite, homogeneous ocean and neglect specific environmental effects, such as water column refraction and bottom reflections. Such factors are an important consideration of underwater sound propagation over extended calculation distances, and thus strongly affect the conditions of the applicability of this methodology.

The acoustic far-field is defined as the distance from a source, which is greater than the acoustic wavelength at a frequency of interest. Since the wavelength varies with frequency, the separation distance will vary with frequency with the lower frequencies having the longer wavelength, as measured in meters (m). The geometric far-field roughly begins at the distance from a source of sound which is greater than roughly four times the largest physical dimension of the area sound source(s). When in the geometric far-field, the sources have all essentially merged into one, so that measurements made even further away will be no different in terms of source contribution. The effects of source geometry and multiple sources operating concurrently, in the geometric far-field, are expected to be negligible. In this report all modeled distances are reported horizontally from the source's acoustic center to determine the average energy flux in a sound field at a given distance.

Scattering and Reflection

Scattering of sound from the surface and bottom boundaries and from other objects is difficult to quantify and is site specific, but is extremely important in characterizing and understanding the received sound field. These interactions were accounted for in the Project acoustic modeling analysis. Reflection, refraction and diffraction from gas bubbles and other inhomogeneities in the propagating medium serve to scatter sound and will affect TL and occur even in relatively calm waters. If boundaries are present, whether they are "real" like the surface of the sea or "internal" like changes in the physical characteristics of the water, they affect sound propagation. The acoustic intensity received depends on the losses due to the path length as well as the amount of energy reflected from each interface. Multiple reflections may occur as the sound reflects alternately from the bottom and the sea surface. It is also very likely that some instances may actually overlap others and cause constructive and destructive interference patterns.

Changes of direction of the sound due to changes of sound velocity are known as refraction. The speed of sound is not constant with depth and range but depends on the temperature, pressure and salinity. Of the three factors, the largest impact on sound velocity is temperature. The change in the direction of the sound wave with changes in velocity can produce many complex sound paths. It may produce locations in the ocean that a sound ray sent out from a particular transducer cannot penetrate. These are called shadow zones. It may also produce sound channels that can trap the sound and allow a signal to travel great distances with minimal loss in energy.

Frequency dependence due to destructive interference forms an important part of this weakening of the signal. Since the inhomogeneities in water are very small compared to the wavelength of the signal, this attenuation-effect will mostly contribute when the signals encounter changes in bathymetries and propagate through the sea floor and the subsurface. For variable bathymetries, the calculation complexity increases, as individual portions of the signal are scattered differently. However, if the acoustic wavelength is much greater than the scale of the seabed non-uniformities, as is most often the case for low-frequency sounds, then the effect of scattering on propagation loss is negligible. Scattering loss occurring at the surface due to wave action will also increase at higher sea states.

Cutoff Frequency

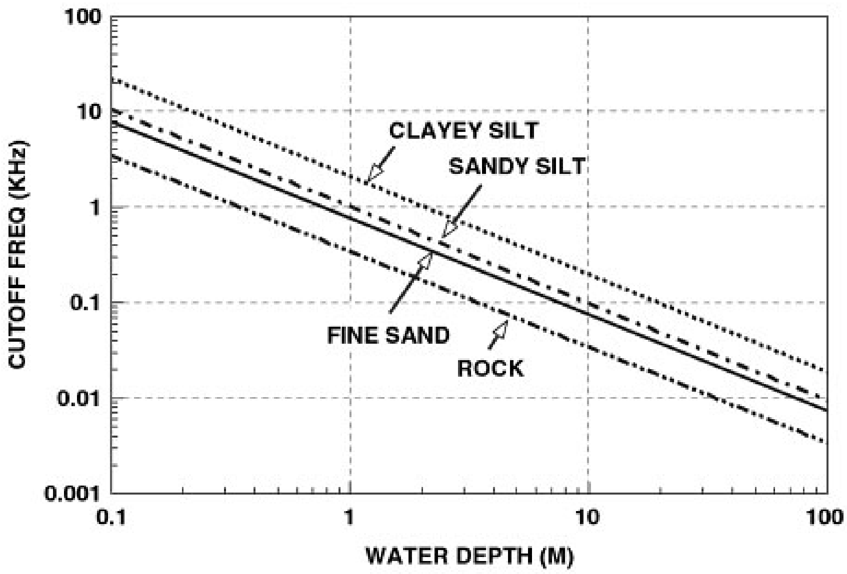
Sound propagation in shallow water is essentially a normal mode where a sound wave moves sinusoidally and has its own frequency and the sound channel is an acoustic waveguide. Each mode is a standing wave in the vertical direction that propagates in the horizontal direction at a frequency dependent speed. Each mode has a cutoff frequency, below which no sound propagation is possible. The cutoff frequency is determined based on the type of bottom material and water column depth. This cutoff frequency (f_c) can also be calculated if the speed of sound in the sediment ($C_{sediment}$) is known (Hastings and Au 2008) and seasonal temperature variation of the speed of sound in seawater (C_{water}) is known using the following equation:

$$f_c = \frac{C_{water}}{4h} / \sqrt{1 - (C_{water})^2/(C_{sediment})^2}$$

Where: f_c = cutoff frequency
C_{water} = speed of sound in water
$C_{sediment}$ = speed of sound in sediment
h = water depth in the direction of sound propagation

In the Project Area, the speed of sound in the sediment is higher than in water, where it is approximated at 1500 meters per second (m/s). Values for speed of sound in sediment will range from 1605 m/s in sand-silt sediment to 1750 m/s in predominantly sandy areas. For example, using the equation above, at a 5 m water depth at the proposed Narragansett cofferdam location, the cutoff frequency f_c is 80 to 160 Hz. This means that underwater noise generated during construction activities at this location will not propagate below this cutoff frequency past the first mode and therefore will not be detected except at very close ranges. Sound traveling in shallower regions of the Project Area will be subject to a higher cutoff frequency and a stronger attenuation than sound propagating as opposed to areas with greater water depths. Figure 1-2 graphically presents the cutoff frequency for different bottom material types.

Figure 1-2 Cutoff Frequencies for Propagation of Sound for Different Bottom Materials (Hastings and Au 2008)



2.0 EXISTING CONDITIONS

The existing underwater acoustic environment is composed of a combination of many possible noise sources of both natural and man-made origins. Noise from natural sources is generated by physical or biological processes. Examples of physical noise sources are tectonic (seismic) activity in the earth's crust (volcanoes and earthquakes), wind and waves; examples of biological noise sources are the vocalizations of marine mammals and fish. There can be a strong minute-to-minute, hour-to-hour, or seasonal variability in sounds from biological sources. Shallow water has been defined for the purposes of this hydroacoustic analysis as a water column less than 200 m deep. Research has shown that ambient noise is 5-10 dB higher in shallower water, which is linked to the influence of surface agitation and reflection by the bottom and may also be dependent on localized conditions of sea state and wind speed, varying both spatially and temporally. The ambient noise for frequencies above 1 kHz is due largely to waves, wind, and heavy precipitation; however, it may be evident at frequencies down to 100-300 Hz during otherwise quiet times (Simmonds et al. 2004). Surface ocean wave interaction and breaking waves with spray have been identified as important sources of noise. Wind induced bubble oscillations and cavitation are also near-surface noise sources, major storms can give rise to noise in the 10-50 kHz band which can propagate to long ranges with the same mechanism and directionality as distant shipping. At areas within distances of 8-10 km to the shoreline land sea water interface, surf noise will be prominent in the frequencies ranging up to a few hundred Hertz (Malme et al. 1995), even during calm wind conditions.

Man-made noise sources can consist of contributions related to industrial plants or construction onshore, offshore oil industry activities, naval operations, and other marine research but the most predominant contributing noise sources would be from ships and other watercraft. Noise from ships dominates marine waters and emanates from the ships' propellers and other rotating machinery such as the main engines, gearboxes, generators, or fans machinery, the hulls passage through the water, and the increasing use of sonar and depth sounders. Other potential ship-related sources include vortex shedding from the hull, noise generated by pipes open to, and discharging into the sea, and noise associated with the wake. Most shipping contributes in a frequency range of less than 1 kHz. In general, older vessels produce more noise than newer ones and larger vessels produce more than smaller ones, but this is not always the case. Although, typically, shipping produces frequencies below 1 kHz, small leisure craft may generate sound with frequency components from 1 kHz, up to the 50 kHz range. Propellers on these vessels tend to cause some cavitation which generates higher frequencies of noise (Simmonds et al. 2004).

Besides these sound sources, a considerable amount of background noise is caused by biological activities. Aquatic animals make sounds for communication, echolocation, and prey manipulation and also as by-products of other activities such as feeding. Biological sound production usually follows seasonal and diurnal patterns, dictated by variations in the activities and abundance of the vocal animals. The frequency content of underwater biological sounds ranges from less than 10 Hz to beyond 150 kHz. Source levels show a great variation, ranging from below 50 to more than 230 dB re 1 µPa RMS at 1 m. Likewise there is a significant variation in other source characteristics such as the duration, temporal amplitude and frequency patterns and the rate at which sounds are repeated (Wahlberg 2012).

A noise budget within the Rhode Island Renewable Energy Zone was created as part of the Rhode Island Ocean Special Area Management Plan (RI Ocean SAMP) through the use of a Passive Acoustic Listening device deployed off the coast of Block Island. The results of this study found that overall, the four main sources of underwater noise were: wind (3,361 picowatts per square meter [pW/m^2]; 97 dB re 1µPa); shipping (3,244 pW/m^2; 97 dB re 1µPa); rain (1,167 pW/m^2; 92 dB re 1µPa); and biological noise (341 pW/m^2; 87 dB re 1µPa) (Miller et al. 2010). The classical Wenz curves, as referenced in RI Ocean

SAMP, provide further information on the possible relationship of sea state relative to ambient underwater sound levels; however, the Wenz data was collected and reported over 45 years ago from finite, principally deepwater offshore locations. More recent U.S. Government funded research and publication is more relevant to the shallow water environment. As stated in an Applied Physics Laboratory (APL) report under the heading Underwater Ambient Noise in Shallow Water: "Unfortunately, simple Wenz-type curves do not suffice to obtain useful estimates in this case (APL 1994). The equations of ambient noise will have to be coded in detail."

3.0 REGULATORY FRAMEWORK

3.1 MMPA Guideline for Lethal and/or Injurious Auditory Effects

Under the 1994 Amendments to the Marine Mammal Protection Act (MMPA), NOAA Fisheries defines the injury threshold as 180 linear decibels (dBL) referenced to 1 µPa RMS (180 dBL re 1 µPa), for mysticetes and odontocetes, and 190 dBL re 1µPa for pinnipeds. These thresholds were determined in relation to a permit for seismic surveys in offshore waters (NOAA 1995); the guidance was subsequently updated to include all odontocetes within the 180 dB re 1µPa sound exposure limit (NOAA 1999). These thresholds consider instantaneous sound pressure levels at a given receiver location. These thresholds are designed to protect all marine species from high sound pressure levels at any discrete frequency across the entire frequency spectrum. They are very conservative criteria as they do not consider species-specific hearing capabilities.

The MMPA defines Level B harassment as any act of pursuit, torment, or annoyance that has the potential to disturb a marine mammal or marine mammal stock in the wild by causing disruption of behavioral patterns, including, but not limited to, migration, breathing, nursing, breeding, feeding, or sheltering. NOAA Fisheries defines the threshold level for Level B harassment at 160 dBL re 1µPa for impulsive sound, averaged over the duration of the signal and at 120 dBL re 1µPa for continuous noise, with no relevant acceptable distance specified. A summary of the NOAA Fisheries cause and effect noise criteria are summarized in Table 3-1.

Table 3-1 Summary of NOAA Fisheries Cause and Effect Noise Criteria

	Criteria Level [a/]	Type
Level A Harassment	180 dBL re 1 µPa (RMS)	Absolute
Level B Harassment	160 re 1 µPa (RMS) 120 re 1 µPa (RMS)	Impulse Continuous
a/ FR 70 Number 7		

These cause and effect thresholds for biological significance consider instantaneous sound pressure levels at a given receiver location. Being expressed in RMS units, the criteria account for not only the energy of the signal, but also the length of a pulse. The NOAA Fisheries acoustic guidelines were purposely developed to be protective of all marine species from high sound pressure levels. However, the sound pressure levels are calculated from unweighted acoustic signals, so they do not account for the different hearing abilities of animals at different frequencies. Also, the NOAA Fisheries (2005) states that such criteria have the disadvantage of not accounting for important attributes of exposure such as duration, sound frequency, or rate of repetition.

NOAA is presently developing acoustic guidelines for assessing the effects of anthropogenic sound on marine mammal species under their jurisdiction. NOAA's draft acoustic guidelines are currently undergoing an internal review. The peer review will focus on scientific and technical studies that have been applied, as well as the manner that NOAA applies them in the guidelines. After peer review, NOAA will seek public comment. Once the peer review and public comments are addressed, NOAA will finalize and release the acoustic guidelines (NOAA Fisheries 2011). Pending approval of these acoustic guidelines, the cause and effect criteria presented in Table 3-1 were used to determine zones of influence for marine mammal species for this Project.

3.2 RI Ocean SAMP Goals

The RI Ocean SAMP provides recommendations to guide the Rhode Island Coastal Resources Management Council (CRMC) in promoting a balanced and comprehensive ecosystem-based management approach for the development and protection of Rhode Island's ocean-based resources within the RI Ocean SAMP study area (RI Ocean SAMP 2011). In Chapter 11 of the RI Ocean SAMP the following policy is given for offshore renewable energy and other offshore development with respect to noise:

- A goal for the wind farm applicant and operator is to have operational noise from wind turbines average less than or equal to 100 dB re 1 μPa^2 in any one-third octave band at a range of 100 m at full power production.
- The applicant and manufacturer should endeavor to minimize the radiated airborne noise from the wind turbines.
- A monitoring system including acoustical, optical and other sensors should be established near these facilities to quantify the effects.

The RI Ocean SAMP goals presented above represent criteria that are perceived as being very protective, given current knowledge of offshore installations. These levels are not to be construed as standards but goals that should be strived for, as they do not take into account cost or feasibility, or the actual or perceived loudness relative to the existing acoustic environment and hearing capabilities of species of concern that may result in biologically significant responses (CRMC Personal Communication).

4.0 ACOUSTIC ANALYSIS METHODOLOGY

Underwater sound and vibration was identified during the scoping process including potential impacts to marine mammals and other marine life in the Project Area and a consensus of scenarios to be reviewed was achieved in consultation with NOAA on October 26, 2011, the CRMC and associated Habitat Advisory Board on December 19, 2011 and March 16, 2012, and the Bureau of Ocean Energy Management (BOEM) on November 3, 2011. Underwater acoustic modeling was completed to assess potential for noise impacts associated with Project construction and operation.

The accuracy of underwater noise modeling results is largely dependent on the referenced sound source data and the accuracy of the intrinsically dynamic data inputs used to describe the medium between the path and receiver including sea surface conditions, water column, and sea bottom. The exact information required can never be obtained for all possible modeling situations, particularly for long-range acoustic modeling of temporally varying sound sources where uncertainties in model inputs increase at greater propagation distances from the source. In these instances, the reliance on a simplistic geometric spreading model such as the inverse power law may be inappropriate for calculation of long range sound propagation in a shallow water channel.

Idealized geometric spreading of sound can only be expected to occur if the velocity of propagation is constant, which is violated in the underwater environment due to variation in temperature with depth. Depending on seasonality, there may be a sound speed gradient created by gradual changes in fluid temperatures. Because of this bending of sound by temperature gradients, some departure from ideal geometric spreading is expected; however, even if this departure are incorporated there are other factors to consider including the boundaries of the medium (ocean bottom and surface), changes in pressure with depth, and the absorption and scattering of sound that occurs in the ocean.

Both the sea surface and bottom affect sound intensity. Some of the sound energy strikes these boundaries and is then partly reflected back into the ocean and partly allowed to pass into the adjacent medium (air or ocean bottom). The portion of the energy which is reflected will return into the interior in many directions. In addition, some sound energy would be converted into heat (absorption of sound) while other obstructions within the ocean such as fish, seaweed, and gas bubbles will scatter sound energy from its principal path. For all of these reasons, the underwater acoustic environment is complex and location-specific due to factors such as bathymetry, seabed composition, seastate conditions, obstructions, and sound speed profile (National Defense Research Committee 1969).

Due to the proposed Project being located in shallow water, sound propagation is essentially characterized by normal mode where a sound wave moves sinusoidally and has its own frequency and the sound channel is an acoustic waveguide. For geometrically shallow water, wave based solutions are generally more useful than ray solutions. As discussed above, the sound from a source will travel through the water directly and by of means reflection from the ocean surface and seabed but will also travel through sediment and rock of the ocean floor and re-emerge at extended distances. Refraction and absorption further distort the waveform, which result in complex spectra that may bear little resemblance to the waveform when it was in the vicinity of the source. Finally, sound may be trapped in sound channels in waters of greater depths when present, with limited attenuation.

Given the required input data to characterize the underwater environment in the Project Area, received sound level results were calculated and plotted. Reasonable and appropriate source level information was derived for WTG operations, WTG impact pile driving, cofferdam vibratory pile and dynamic position

(DP) vessels. The source level information and source depth are additional inputs to the acoustic propagation model and are further discussed in Section 6.0 of this report. Other site-specific parameters including bathymetry and geoacoustic profiles of the seabed are also incorporated in the modeling calculations. More details pertaining to these inputs are given in Section 5.0 of this report. Other sources of noise include onboard machinery, jack-up gears, and vessel propellers; however, these noise sources are unlikely to emit source levels sufficient to reach or exceed NOAA regulatory criteria for marine mammals.

4.1 Sound Propagation Model

The Acoustic Toolbox User Interface Post processor (AcTUP) is written in Matlab by HLS Research and is a Graphical User Interface distributed by the Center for Marine Science and Technology at Curtain University. This interface provides a platform for running multiple propagation routines, allowing analyses of acoustic propagation of signals through the underwater channel by numerically solving propagation equations. Acoustic modeling was completed with the widely-used the Range Dependent Acoustic Model (RAM) which is based on the U.S. Navy's Standard Split-Step Fourier Parabolic Equation (PE) (Collins et al. 1996). RAM is based on the parabolic equation method using the split-step Padé algorithm for improved numerical accuracy and efficiency in solving range dependent acoustic problems and is commonly used for acoustic analysis in the offshore underwater environment (Collins 1993). This methodology consists of a set of algorithms that calculates TL based on a number of factors including the distance between the source and receiver along with basic ocean parameters (e.g., depth, bathymetry, geoacoustic properties of sediment type, and the ocean's temperature-depth profile).

RAM is an extremely efficient PE code that copes naturally with range-dependent environments and overcomes the principle limitation of the PE method; lack of accuracy for energy propagating at large angles to the horizontal (Duncan and Maggi 2006). Use of the PE method allows for a one-way wave equation that can be solved by a range-marching technique with a proper starting field (i.e., near-field underwater sound pressure level). The forward propagating field is obtained at a given range from the field at a previous range and appropriate boundary conditions at the top and bottom of the domain, in other words the solution (i.e., the underwater received sound pressure level) is marched in range. The computational advantage of parabolic approximation is the elliptic reduced wave equation is numerically solved in the entire range-depth plane simultaneously. The RAM acoustic modeling methodology has been benchmarked for accuracy and is recognized and used by acoustic engineers in modeling underwater environmental sound scenarios. RAM assumes that outgoing reflected and refracted sound energy dominates scattered sound energy and computes the solution for the outgoing (one-way) wave equation. At low frequencies, the contribution of scattered energy is very small compared with the outgoing sound field. An uncoupled azimuthal approximation is used to provide gridded two-dimensional TL values in range and depth with a geo-referenced dataset to automatically retrieve the bathymetry and acoustic environment parameters along each propagation transect radiating from the sound source.

The received sound field within each vertical radial plane is sampled at various ranges from the source with a fixed radial step size. At each sampling range along the surface, the sound field is sampled at various depths, with the step size between samples increasing with depth below the surface. The received sound level at a given location along a given transect is taken as the maximum value that occurs over all samples within the water column below. The TL values produced by the model are used to attenuate the spectral acoustic output levels of the corresponding sound source to generate an estimate of the received sound levels along a given transect. These values are then summed across frequencies to provide broadband received levels at the MMPA level A and B harassment criteria as described in Section 3.1.

The critical distances to the MMPA criteria are visually displayed on a georeferenced orthophoto along each major directional transect from the sound source being evaluated and provide key information in determining potential zones of impact during Project activities. These data may be used to estimate how many marine mammals and other species of concern would receive a specified amount of sound energy in a given time period and for use in developing monitoring and/or mitigation programs, as necessary.

4.2 Bathymetry

For geometrically shallow water, sound propagation is dominated by boundary effects. Bathymetry data represent the 3D nature of the subaqueous land surface and was obtained from the National Geophysical Data Center (NGDC) U.S. Coastal Relief Model (NOAA Satellite and Information Service 2005); the horizontal resolution of this data set is 3 arc-seconds. NGDC's 3 arc-second U.S. Coastal Relief Model (CRM) provides the first comprehensive view of the U.S. coastal zone, integrating offshore bathymetry with land topography into a seamless representation of the coast. The CRM spans the U.S. East and West Coasts, the northern coast of the Gulf of Mexico, Puerto Rico, and Hawaii, reaching out to, and in places even beyond, the continental slope. The Geophysical Data System (GEODAS) is an interactive database management system developed by the NGDC for use in the assimilation, storage and retrieval of geophysical data. GEODAS software manages several types of data including marine trackline geophysical data, hydrographic survey data, aeromagnetic survey data, and gridded bathymetry/ topography.

The datasets, originally with a horizontal resolution of 20 m, were linearly interpolated on a regular grid. The bathymetric data was sampled by creating a fan of radials at a given angular spacing. This grid was then used to determine depth points along each modeling radial transect. The underwater acoustic modeling takes place over these radial planes in 100 m increments at the sampled depth. These radial transects were used for modeling both the construction and operation of the Project, with each radial centered on the given Project sound source or activity. Figure 4-1 presents the bathymetries within the Project Area.

4.3 Geoacoustic Properties

Sediment type (e.g., hard rock, sand, mud) directly impacts the speed of sound as it is a part of the medium in which the sound propagates. The propagation efficiency of the seabed is far less than that of the water column because of the intrinsic absorption of the bottom is typically about 1,000 times that in seawater. Because of variations in water depth and in ocean bottom properties, ocean noise in shallow water can be highly variable from one location to another.

Sediment information for the Project Area was obtained from the United States Geological Survey Continental Margin Mapping Program, which includes an extensive east coast sediment study. Geoacoustic properties were defined up to a maximum depth of 225 feet (ft) below the WTG 3 site, which was the maximum depth of the available geological data, and transitioned to a common geoacoustic profile in other areas. Table 4-1 presents order of magnitude acoustic parameters for common sediments and seafloor conditions.

Figure 4-1 Bathymetry of the Project Area

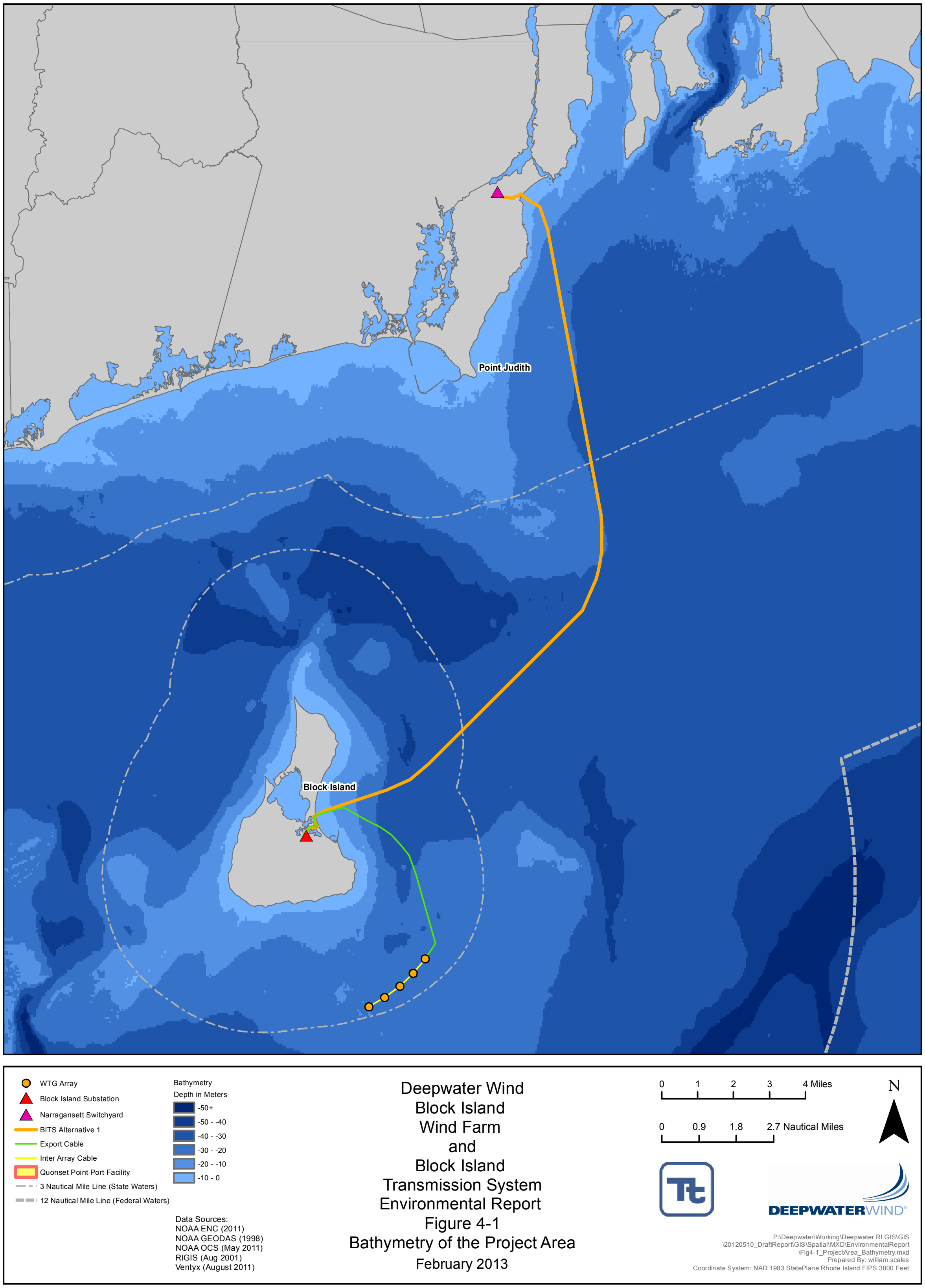


Table 4-1 Geoacoustic Parameters for Sediments[2]

Sediment Type	M (Φ)	N (%)	P (kgm^{-3})	c_r	c(m/s)	V(0°) (dB)	αs (dB/λ)	c_3 (m/s)	Ω_0 (cm^4)	h(cm)	δ {°}
Clay	9	80	1,200	0.98	1,470	-21.8	0.08	-	5×10^{-4}	0.5	1.2
Silty clay	8	75	1,300	0.99	1,485	-18.0	0.10	-	5×10^{-4}	0.5	1.5
Clayey silt	7	70	1,500	1.01	1,515	-13.8	0.15	125	5×10^{-4}	0.6	1.3
Sand-silt-clay	6	65	1,600	1.04	1,560	-12.1	0.20	290	5×10^{-4}	0.6	2
Sand-silt	5	60	1,700	1.07	1,605	-10.7	1.00	340	5×10^{-4}	0.7	2.5
Silty sand	4	55	1,800	1.10	1,650	-9.7	1.10	390	1×10^{-3}	0.7	3
Very fine sand	3	50	1,900	1.12	1,680	-8.9	1.00	410	2×10^{-3}	1.0	4
Fine sand	2	45	1,950	1.15	1,725	-8.3	0.80	430	3×10^{-3}	1.2	5
Coarse sand	1	40	2,000	1.20	1,800	-7.7	0.90	470	7×10^{-3}	1.8	6
Source: Hamilton 1976, 1982; Hamilton and Bachman 1982; APL 1994.											

The geoacoustic properties of these materials include compressional speed (c_p), density (ρ), P-attenuation (αp), shear speed (c_s) and S-attenuation (αs), and vary with depth (z). Bottom loss is a complex and only partly understood phenomenon. Figure 4-2 graphically presents estimated attenuation factors as a function of signal frequency (kHz) for several different bottom types. The bottom type in the Project Area is predominantly sand, and is expected to result in comparatively higher attenuation rates with increased distance from the source. The near-field anomaly which describes attenuation in the acoustic near-field, dependent on seastate and bottom conditions, is presented on the left axis. The (k_L) anomaly is a theoretical term related to the reverberant sound field developed near the source by surface and bottom reflected sound energy resulting in an apparent increase in received sound levels in immediate proximity to the source.

4.4 Sound Speed Profiles

The speed of sound in sea water depends on the temperature T [°Celsius], salinity S [ppt], and depth (D in m) and can be characterized using sound speed profiles (SSPs). The SSP of an underwater environment has a significant effect on sound attenuation. Oftentimes, a homogeneous or mixed layer of constant velocity is present in the first few meters. It corresponds to the mixing of superficial water through surface agitation. There can also be other features such as a surface channel, which corresponds to sound velocity increasing from the surface down. This channel is often due to a shallow isothermal layer appearing in winter conditions, but can also be caused by water that is very cold at the surface. In addition, a thermocline is a monotonous variation of temperature with depth. It is most often negative and then induces a velocity decrease with depth. It can be seasonal or permanent (Lurton 2010).

[2] Hamilton, E.L. 'Compressional Waves in marine sediments', Geophysics, 37 620-646, 1982.
Hamilton, E.L. 'Geoacoustic modeling of the sea floor', Journal of the Acoustical Society of America, 68, 1313-1340, 1976.
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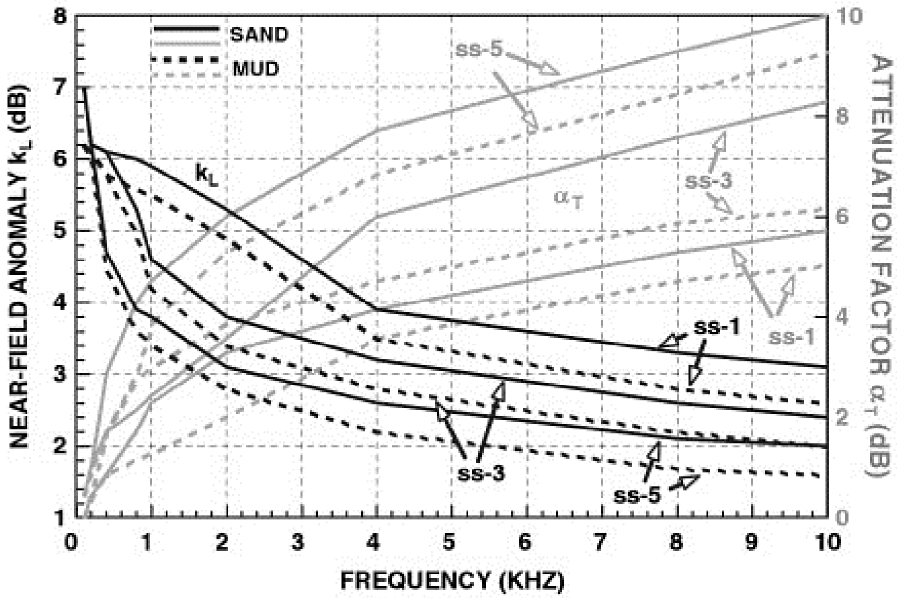
APL, APL-UW High-Frequency Ocean Environmental Acoustic Models Handbook (APL-UW TR 9407). Seattle, WA: Applied Physics Laboratory, University of Washington, 1994.

Figure 4-2 Near-field Anomaly and Shallow Water Bottom Attenuation Factor as a Function of Frequency



Water column SSPs were calculated from profiles downloaded from the U.S. Naval Oceanographic Office's Generalized Digital Environmental Model (GDEM) database. The latest release of the GDEM database provides average monthly profiles of temperature and salinity for the world's oceans on a latitude-longitude grid with 0.25-degree resolution. Profiles in GDEM are provided at 78 fixed depth points up to a maximum depth of 6800 m. The profiles in GDEM are based on historical observations of global temperature and salinity from the U.S. Navy's Master Oceanographic Observational Data Set. GDEM is a climatology meaning it represents the long-term mean. It will not be changed in a statistically meaningful way by including data from a single exercise or oceanographic survey unless these new data were in a region where little data previously existed. Temperature-salinity profiles from GDEM can then be converted to SSPs using the equations of Mackenzie (1981):

$$c\ [\text{m/s}] = 1448.96 + 4.591\,T - 5.304 \times 10^{-2}\,T^2 + 2.374 \times 10^{-4}\,T^3 + 1.340\,(S - 35) + 1.630 \times 10^{-2}\,D + 1.675 \times 10^{-7}\,D^2 - 1.025 \times 10^{-2}\,T(S - 35) - 7.139 \times 10^{-13}\,TD^3$$

In a negative sound gradient, as shown in the April, May, June, July, and August plots, sound speed decreases with depth, which results in sound refracting downwards which may result in increased bottom losses with distance from the source. In a positive sound gradient as predominantly present in the winter season, sound speed increases with depth and the sound is therefore refracted upwards, which can aid in long distance sound propagation. Figures 4-3 and 4-4 present SSPs corresponding to months when Project activities are expected to occur. For geometrically shallow water, the shape of the sound speed profile will have somewhat less influence on propagation than in deep water, but these inputs were included due to the fairly high seasonal variation.

Figure 4-3 Average Spring and Summer Monthly Sound Speed Profiles as a Function of Depth

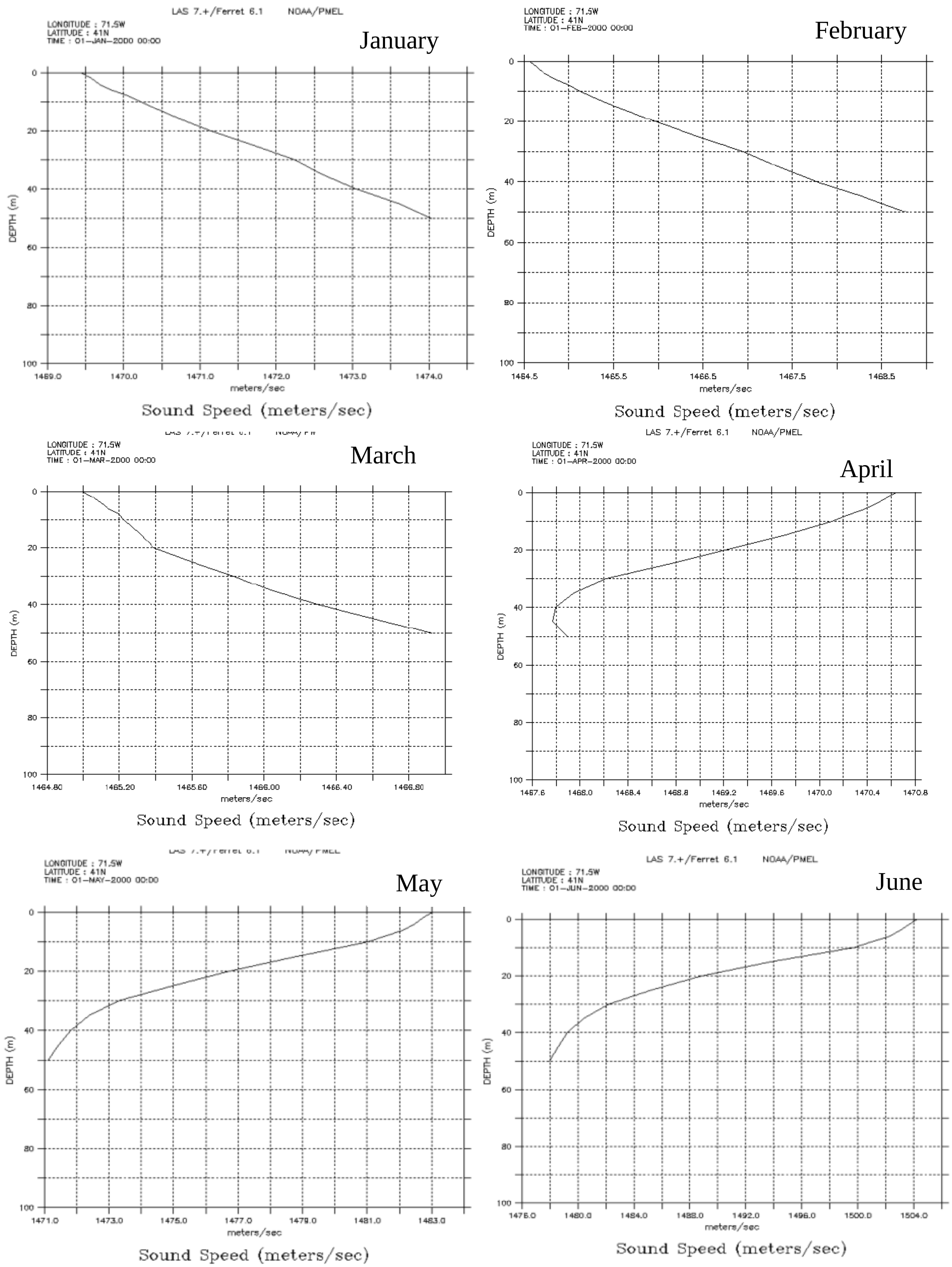
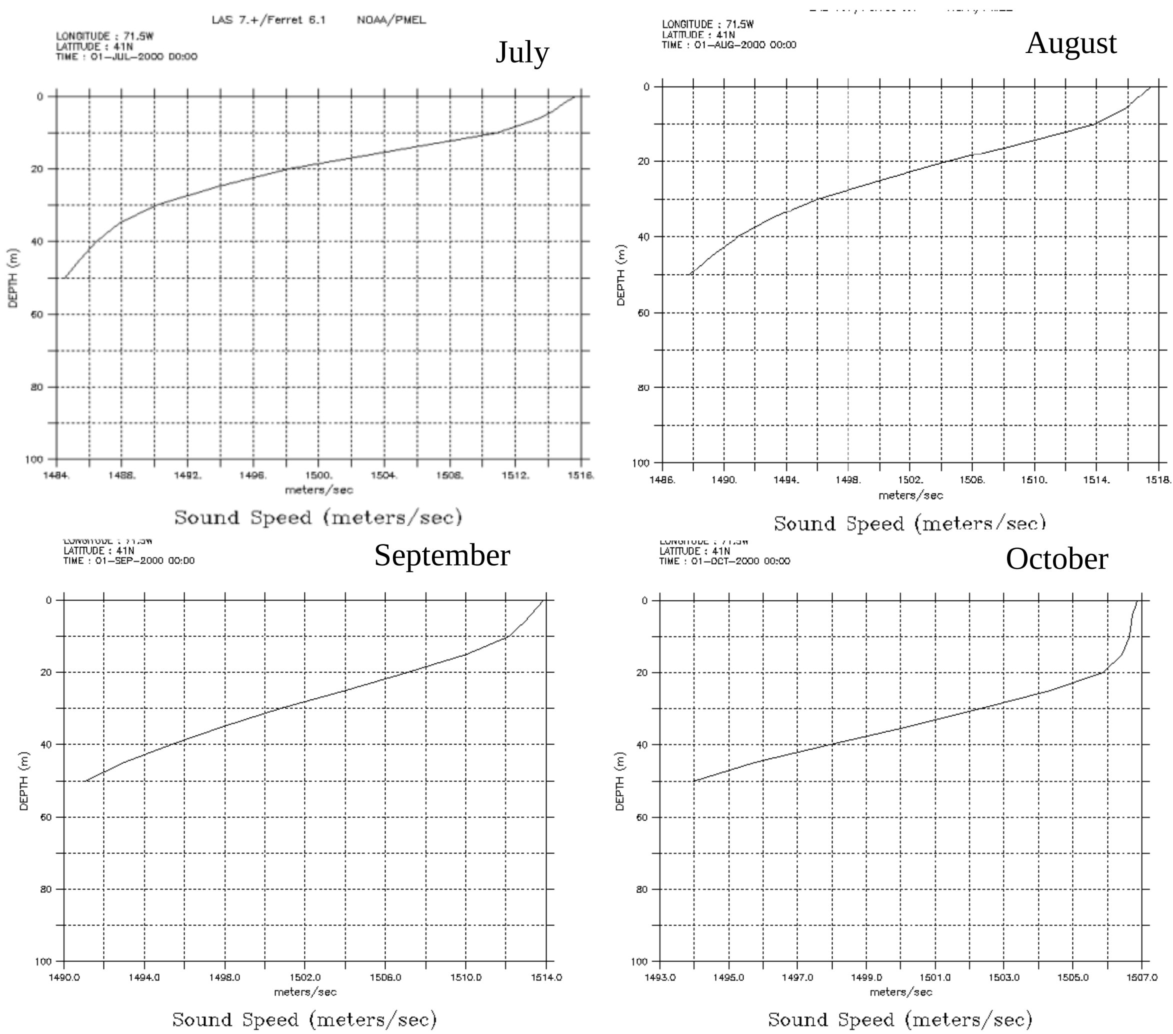


Figure 4-4 Average Winter Monthly Sound Speed Profiles as a Function of Depth



5.0 MODELING SCENARIOS

The scenarios considered were based on descriptions of the expected construction and operations activities outlined in the project description. The subsections that follow provide more detailed information about the parameters used to model the noise sources associated with each activity. Source level measurements were unavailable for several vessels and activities identified at the time of writing. Therefore, a literature review was conducted in order to identify source level measurements from comparable equipment performing similar activities. Source levels for these proxy noise sources were used as model input parameters. Appendix A provides one-third octave band source levels for each of the acoustic modeling scenarios.

Table 5-1 Construction and Operations Activities by Model Scenario

Scenario	Description	UTM NAD83 UTM Zone 19	Anticipated Schedule	Source Level (dB re 1μPa·m)
Scenario 1a & 1b	Hydraulic Pile Driving of WTG 3 25 m water depth	288325.1 4554557.7	May – July or August – October	213 (200 KJ) 219 (600 KJ)
Scenario 2a and 2b	Vibratory Sheet Pile Driving of Cofferdam 5 to 6 m water depth	Narragansett 295154.3 4589532.1 Block Island 298270.9 4595793.9	December – June	194
Scenario 3	DP Vessel Maneuvering (Water Depth = 10 m), Thruster Power = 50%	295519.0 4589372.3	April to August	180
Scenario 4	DP Vessel Maneuvering (Water Depth = 20 m), Thruster Power = 50%	286784.8 4562192.2		180
Scenario 5	DP Vessel Maneuvering (Water Depth = 40 m), Thruster Power = 50%	297218.9 4571619.6		180
Scenario 6	WTG 3 in Operation 25 m water depth	288325.1 4554557.7	Continuous once Project Commences Operations	TBD

6.0 ACOUSTIC SOURCE LEVELS

By convention, underwater acoustic source levels are defined as the acoustic pressure at 1m distance from a point source [dB re 1 µPa @ 1m]. In the source-path-receiver model of sound propagation, the received SPL at some receiver position is equal to the source level minus the TL along the propagation path between the source and the receiver. For sources that are physically much larger than a cubic meter (m^3), i.e. ship propellers, the sound pressure is measured at some range, and a propagation model is applied to compute what the pressure would have been at a 1m range if represented as an idealized point source.

The level of an acoustic source is a measure of the acoustic output of that source and is a far-field, free-field property of the source. It is related to the radiant intensity and acoustic power of the source, but it is rarely described in these terms. The source level is sometimes stated as a spectral level (as a function of frequency – e.g., in one-third octave bands) or as a broadband level (summed over all the frequencies of radiation).

The sound from a source can travel through the water directly and by means of reflection from ocean surface and seabed. Sound may also travel through sediment and rock of the ocean floor and re-emerge at extended distances. Refraction and absorption further distort the waveform, which result in complex spectra which may bear little resemblance to the waveform in immediate vicinity of the source. Finally, sound may be trapped in sound channels in waters of greater depths, with limited attenuation with increasing distance from the source. Reasonable and appropriate source level information were derived for WTG operation, vibratory and impact pile driving, and DP vessels. The source level descriptions and source depth assumptions are key inputs to the acoustic propagation model. Proxy source levels for each of the modeling scenarios presented in this report were derived from literature, engineering guidelines, and underwater source measurements of similar equipment and activities. Actual source levels may vary and will be validated by Deepwater Wind during construction and operation activities, as appropriate. Deepwater Wind will also review and, if necessary, revise the propagation modeling analysis for DP vessels after a specific vessel has been procured for cable installation.

6.1 Scenario 1: Impact Pile Driving

The driving of large steel shell piles has been found to result in high underwater sound pressures that may be lethal to fish and potentially dangerous to marine mammals and sea turtles. Impact pile driving involves weight hammers that pile into the seafloor. Different methods for lifting the weight include hydraulic, steam or diesel. The acoustic energy is created upon impact; travels into the water along different paths (1) from the top of the pile where the hammer hits, through the air, into the water; (2) from the top of the pile, down the pile, radiating into the air while travelling down the pile, from air into water; (3) from the top of the pile, down the pile, radiating directly into the water from the length of pile below the waterline; and (4) down the pile radiating into the ground, travelling through the ground and radiating back into the water.

Near the pile, acoustic energy arrives from different paths with different associated phase and time lags which creates a pattern of destructive and constructive interference. Further away from the pile, the water and seafloor borne energy are the dominant pathways. Noise increases with pile size (diameter and wall thickness), hammer energy, and subsurface hardness. According to available Project design information, the piles are expected to be between 42 and 54 inches in diameter, with a maximum wall thickness of 1.5 inches and a design penetration between 160 and 250 ft below the seabed. Within a steel pile, the speed of sound is about 5,000 m/s, while the speed of sound in water is about 1,500 m/s. Finalization of WTG design considerations and pile driving methodologies may alter these numbers.

Source levels were derived following an extensive literature review of documents, technical reports and peer-reviewed research papers to identify source level measurements from similar equipment performing similar activities. Documents reviewed included the Caltrans *Technical Guidance for Assessment and Mitigation of the Hydroacoustic Effects of Pile Driving on Fish*, the Caltran's *Technical Guidance for Assessment and Mitigation of the Hydroacoustic Effects of Pile Driving on Fish*, and the Blackwell paper *Underwater Measurements of Pile Driving Sounds during the Port MacKenzie Dock Modifications*, among several others. However, these documents and measurement data were principally set in river estuaries and protected bays, or consisted of near-field measurement data, which serve as useful data but principally limited to the study of fish mortality. More relevant data were obtained in a review of recent European and U.S. research and technical documents on offshore wind energy and meteorological data collection facility construction, which served as the basis of the acoustic source data for the current analysis.

Table 6-1 presents underwater sound measurement data collected for impact pile driving with similar pile diameter, water column depths, seafloor characteristics, and impact forces, in the context of an offshore oceanic environment (ITAP 2007). It is assumed that far-field conditions apply at all measurement distances. These data were normalized for BIWF site-specific conditions and impact hammer forces. Research has shown that that the noise level increases by 13 $\log_{10}$ (E_2/E_1) if the blow energy is increased from E_1 to E_2 (Schultz-von et al. 2006; Robinson et al. 2007). The normalization methodology is described in the following equation:

$$L_{normalized} = L_{measured} + 10\log_{10}\left(\frac{25}{H_1}\right) + 15\log_{10}\left(\frac{R_1}{500}\right) + 13\log_{10}\left(\frac{600}{E_1}\right)$$

Where: L = sound pressure level

H_1= depth at which the original pile driving measurement was completed

R_1 = distance at which the original measurement was taken

E_1 = impact hammer force for the original measurement

E_2 = estimated hammer force 600 kilojoule (KJ)

The last three columns of Table 6-1 show three different sound metrics, which were all normalized to a distance of 500 m. These sound levels metrics were reported in terms of the measured peak sound level, the measured SEL and the 90 percent RMS sound level ($RMS_{90\%}$). These sound descriptors are presented because pile driving sound is characterized as impulsive, which has somewhat unique features in comparison to other sounds. Impulsive sounds can have moderate average, but very high instantaneous pressure peaks, which might be harmful to the auditory system. The measured peak sound level represents these high instantaneous pressure peaks. For purposes of Table 6-1, SEL is the level of a sound averaged over a stated 1 second duration with the same sound energy as occurring at the instantaneous peak. The SEL may be more appropriate for assessing masking effects at larger distances from the source and assessing cumulative sound exposure which may be necessary in the evaluation of potential physiological impacts. The measured SELs range from 173 to 178 dBL. Recent studies of underwater sound generated during impact pile driving have also employed a RMS sound pressure "averaged over the duration of the pulse." A typical pile driving impulse lasts approximately 125 milliseconds with principal energy contained within the first 30 to 40 milliseconds.

Table 6-1 Summary of Representative Underwater SEL and $RMS_{90\%}$ Normalized to the Deepwater BIWF Site Conditions and Expected Range of Pile Driving Impact Forces during Construction

Measurement Site	Pile Diameter m	Measured Depth H1 m	Measured Distance R1 m	Impact Energy E1 KJ	Apparent Source Level 200 KJ	MEASURED SPLs			SEL re 1 $\mu Pa^2 s$ NORMALIZED TO 500 m		$RMS_{90\%}$ re 1 μPa NORMALIZED TO 500 m	
					$RMS_{90\%}$ re 1 μPa @ 1m	PEAK re 1 μPa	SEL re 1 $\mu Pa^2 s$	$RMS_{90\%}$ re 1 μPa	Standard 200 KJ	MAX 600 KJ	Standard 200 KJ	Max 600 KJ
Jade Port Construction Works, Germany, 2005	0.9	11.0	340	135	214	188	162	171*	165	171	174	180
Jade Port Construction Works, Germany, 2005	1.0	11.0	340	135	216	190	164	173*	167	173	176	182
FINO 1, Germany, 2003	1.6	30.0	400	140	211	192	162	171*	162	168	171	177
Cape Wind MDCF, 2002	1.0	13.5	500	200	213	n/a	161	170*	164	170	173	179

* Data reported in terms of SEL only. $RMS_{90\%}$ values estimated assuming a 125 millisecond pulse.

An integration period (T90) of the RMS signal inclusive of 90 percent of the sound energy has been calculated to result in a net 9 dBL increase relative to the reported SEL values shown in Table 6-1, when approximated as a 3 dB increase of each halving of the 1-second SEL signal duration. This semi-empirical relationship between SEL and $RMS_{90\%}$ is expected to hold for relatively short ranges; however, at increasing ranges from the source, distortion of the pulse duration will occur, especially in shallow water environments similar to that of the Project Area.

Although data from the referenced studies in Table 6-1 are too far away from their sources to provide reliable near-field estimates (i.e., sound levels in immediate proximity of the pile itself), for comparative purposes, apparent source levels were estimated for a 600 KJ impact force. Back-calculating source levels from measurements made in the acoustic far-field is subject to a very high level of uncertainty. Therefore, apparent source levels, which are referenced to 1 m in Table 6-1, are intended for comparative purposes and as rough estimates only, as there are large variations in reported source levels for impact hammer pile driving

For the purpose of the underwater acoustic analysis of the Project, Deepwater Wind Block Island, LLC has determined that the pile driving would initially start with a 200 KJ impact force, and be ramped up to a maximum 600 KJ impact force to reach final design penetration and seat the piles. A 1000 KW unit will power the hydraulic hammer. Duration of pile driving is anticipated to be 4 days per jacket. Pile driving activities will occur during daylight hours starting approximately 30 minutes after dawn and ending approximately 30 minutes prior to dusk unless a situation arises where ceasing the pile driving activity would compromise safety (both human health and environmental) and/or the integrity of the Project. Each jacket will require 7 days to complete installation. Jackets will be installed one at a time at each WTG location for a total of 5 weeks assuming no delays due to weather or other circumstances. To be conservative, the Project has assumed that the full impact force of 600 KJ may be required during WTG construction.

6.2 Scenario 2: Vibratory Pile Driving

The exit point of the long-distance HDDs will be offshore. Should this option be selected, temporary offshore cofferdams will be required. No offshore cofferdams will be required if the short-distance HDD option is selected.

If required, the temporary offshore cofferdams will be constructed by installing steel sheet pile in a tight configuration around an area of approximately 20 ft by 50 ft. Vibratory pile drivers install piling into the ground by applying a rapidly alternating force to the pile. This is generally accomplished by rotating eccentric weights about shafts. Each rotating eccentric produces a force acting in a single plane and directed toward the centerline of the shaft. The weights are set off-center of the axis of rotation by the eccentric arm. If only one eccentric is used, in one revolution a force will be exerted in all directions, giving the system a good deal of lateral whip. To avoid this problem the eccentrics are paired so the lateral forces cancel each other, leaving only axial force for the pile.

The resultant overall noise footprint associated with a vibratory hammer is typically less than that of an impact hammer. Additionally, it is expected that exposure to noise of a vibratory hammer is very unlikely to induce injury due to its much reduced peak pressure levels associated with the vibratory hammer. For estimating source levels and frequency spectra, the vibratory pile driver was estimated assuming an 1800 kilonewton (kN) vibratory force. Modeling was accomplished using adjusted one-third-octave band vibratory pile driving source levels from measurements of a similar offshore construction activity, and adjusted to account for the estimated force necessary for driving Project cofferdam sheet piles.

6.3 Scenarios 3 through 5: Dynamic Positioning Vessels during Cablelay

The Export Cable will connect the WTGs to a new substation on Block Island (Export Cable); the BITS will connect Block Island to the electrical transmission grid on the Rhode Island mainland. The Export Cable and BITS cable have a 6- to 10-inch (15.2- to 25.4-centimeter) diameter and will require a trench width corridor up to 5 ft (1.5 m) wide and a plow skid width up to 15 ft (4.6 m) during construction. The Export Cable and BITS cable will be buried at a target depth of 6 ft (1.8 m) beneath the seafloor. The actual burial depth will depend on substrate encountered along the route and could vary from 4 ft to 8 ft (1.2 m to 2.4 m).

Barges are not under their own power and do not contribute substantially to the underwater noise levels. DP vessels will use thrusters, which are known to be contributors of noise. Representative sound source data were reviewed to provide an estimate for representative DP vessel source level which is dependent on the hydrodynamic and hydroacoustic design and depth of the vessel thrusters that will be used during installation of the Export and BITS cable. Hydroacoustic modeling calculations were completed at three representative locations along the cable lay line consisting of water depths of 10 m (Scenario 3), 20 m (Scenario 4) and 40 m (Scenario 5).

DP systems maintain their precise coordinates in waters through the use of automatic controls. These control systems use variable levels of power to counter forces from current and wind. Sound generated by DP vessels was estimated at 100% power level (8,000 HP) and at a reduced 50% power level (approximately 4,000 HP). During actual cablelay activities it is expected that the reduced 50% power level will be used by DP vessels. This assumption was incorporated into the acoustic modeling analysis. The adjusted sound level for reduced power is given in the following formula based on the engine horsepower:

$$SL = SL\ \text{original} + 10\log\left(HP/HP_{REF}\right)$$

Where:

SL	Source level
HP	Horsepower (50%)
HP_{REF}	Reference Horsepower (100%; 8000 HP)

Table B-1 in Appendix B provides octave band spectrum data corresponding to the DP operation at the reduced 50% power level. The assumptions used for DP vessel sound power will be validated once final vessel selection has been made prior to Project construction. Additional modeling of thruster use based on the final procured vessel will be conducted and a revised report will be submitted including updated distances to relevant MMPA thresholds, if necessary.

6.4 Scenario 6: Operational Wind Turbines

WTGs produce low level sound during operation. There is a limited amount of published data on WTGs of this design and jacket type foundation. Based on monopole foundation types, general comparisons can be made on the expected region of insonification.

7.0 MODEL RESULTS

By employing field verified underwater measurement data during similar operations, resultant sound levels are representative of vessels and equipment that are likely to be employed and are not expected to be exceeded under the majority of real world conditions. The use of the loudest construction events adds to the overall conservatism of the calculations. Acoustic modeling algorithms were applied to estimate received sound levels from various Project construction and operational phases to determine distances at biologically significant threshold levels as defined by NOAA. The results of the hydroacoustic modeling calculations are presented in two different formats. For each modeling scenario the model calculation output was used to produce aerial mapping showing the critical MMPA threshold levels in Appendix A. Tables of distances to MMPA threshold values are presented in Appendix B. Table 7-1 presents a summary of the maximum distances to MMPA threshold values for each hydroacoustic modeling calculation presented in Appendix B. Maximum distances to harassment thresholds will be used as a conservative approach to determine zones of influence for marine mammal species. The results do not include existing acoustic underwater ambient conditions.

Table 7-1 Distances to MMPA Thresholds from BIWF and BITS Project Construction Activities

Source	Distance to 180 dBL MMPA Threshold (m)	Distance to 160 dBL MMPA Threshold (m)	Distance to 120 dBL MMPA Threshold (m)
Impact Pile-Driving (Hammer Energy = 600 KJ) [a/c/]	600	7,000	N/A
Impact Pile-Driving (Hammer Energy = 200 KJ) [b/c/]	200	3,600	N/A
DP Vessel Maneuvering (Water Depth = 10 m), Thruster Power = 50% [d/]	--	N/A	4,750
DP Vessel Maneuvering (Water Depth = 20 m), Thruster Power = 50% [d/]	--	N/A	4,275
DP Vessel Maneuvering (Water Depth = 40 m), Thruster Power = 50% [d/]	--	N/A	3,575
Vibratory Pile-Driving (Block Island) [e/]	--	350	> 40,000
Vibratory Pile-Driving (Narragansett) [e/]	--	300	> 40,000

a/ Will be used only to drive piles to final penetration depth.
b/ Primary hammer for foundation pile installation.
c/ Impact pile-driving is considered an impulsive sound source.
d/ DP vessels are considered continuous sound sources.
e/ Vibratory pile-driving is considered an impulsive/short-term continuous sound source.

7.1 Block Island Wind Farm

7.1.1 Construction

Predicting underwater noise levels during offshore pile driving is of great interest to the Project and pile installation contractors who must demonstrate compliance with stringent MMPA threshold values. Sound propagation modeling was performed using RAMGeo for BIWF construction scenarios (see Section 5 for scenario details). For Scenarios 21a and 1b (Figure A-1 and A-2, respectively), sound levels by direction to the NOAA safety thresholds are represented. Resultant sound levels show the total sound energy contained in a single pile driving pulse. Despite issues associated with the pulse duration, accurate estimates of pile driving safety ranges must take into account the acoustic energy that is returned to the water column by bottom and surface reflections. This is especially important in the case of shallow water, where multiple reflections are likely, and individual pulses of sound will distort as they propagate. For computing RMS SPLs from marine pile driving, far-field pressure waveforms were conservatively estimated as a function of water depth and distance from the source as a result of time stretching of the pulse due to multiple reflections. Geometrical spreading is expected to be a good approximation to actual peak pressure decay, at short ranges, where high peak and impulsive levels are normally encountered. The results of the underwater acoustic modeling analysis indicate received sound levels that are consistent with similar offshore construction activities.

Once vessel procurement is completed, Deepwater Wind Block Island, LLC will review and, if necessary, revise the propagation modeling analysis for DP vessels based on actual vessel specifications. To verify distances calculated by underwater acoustic modeling performed for the BIWF, Deepwater Wind Block Island, LLC has committed to conducting real-time underwater acoustic measurements of noise-producing activities at the start of construction for each activity. Field verification of actual sound propagation will enable adjustment of the critical MMPA threshold level distances to fit actual construction conditions, if necessary.

7.1.2 Operation

The distance to the 120 dB threshold is estimated at 100 to 200 m from a single turbine. Noise levels of the operating wind farm are too low to cause injury to marine mammals and the ranges to the injury thresholds for continuous noise were not computed from the model results. There is no data on impact thresholds for fish, invertebrates and marine birds exposed to continuous noise. As part of the goal of this demonstration project, underwater noise will be monitored and observed during a 1-week real-time monitoring period to collect data on the full range of WTG operational conditions.

7.2 Block Island Transmission System

7.2.1 Construction

Sound propagation modeling was performed using RAM for the BITS construction scenarios (see Section 5). Noise generated by DP vessels during cable lay was assessed at three positions. Figures A-5 through Figure A-7 present the geographically-rendered results for the three discrete water depths. Resultant sound levels associated with DP vessels correspond to thruster use at 50% of the maximum DP power rating, or approximately 4000 HP. The directional critical distances shown in each map represent the maximum received RMS SPL sound levels over all depths at the NOAA criteria thresholds. The use of a vibratory pile driver will be necessary for construction of the cofferdams. For Scenarios 2a and 2b (Figure A-3 and A-4), directional distance plots for the two cofferdam locations are presented during vibratory pile driving. The levels reported for the BITS cable lay and cofferdam construction are well within the level range measured for comparable situations elsewhere.

Once vessel procurement is completed, Deepwater Wind Block Island Transmission, LLC will review and, if necessary, revise the propagation modeling analysis for DP vessels based on actual vessel specifications. To verify distances calculated by underwater acoustic modeling performed for the BITS, Deepwater Wind Block Island Transmission, LLC has committed to conducting real-time underwater acoustic measurements of noise-producing activities at the start of cable installation. Field verification of actual sound propagation will enable adjustment of the critical MMPA threshold level distances to fit actual construction conditions, if necessary.

7.2.2 Operation

Operation of the BITS system will not appreciably increase underwater sound levels; therefore, no underwater acoustic monitoring is warranted.

8.0 REFERENCES

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APPENDIX A

Figures

Figure A-1 Scenario 1a: Received Sound Levels during 200 KJ Impact Hammer Pile Driving of a 1.37 m Diameter Steel Pile for the WTG Jacked Foundation

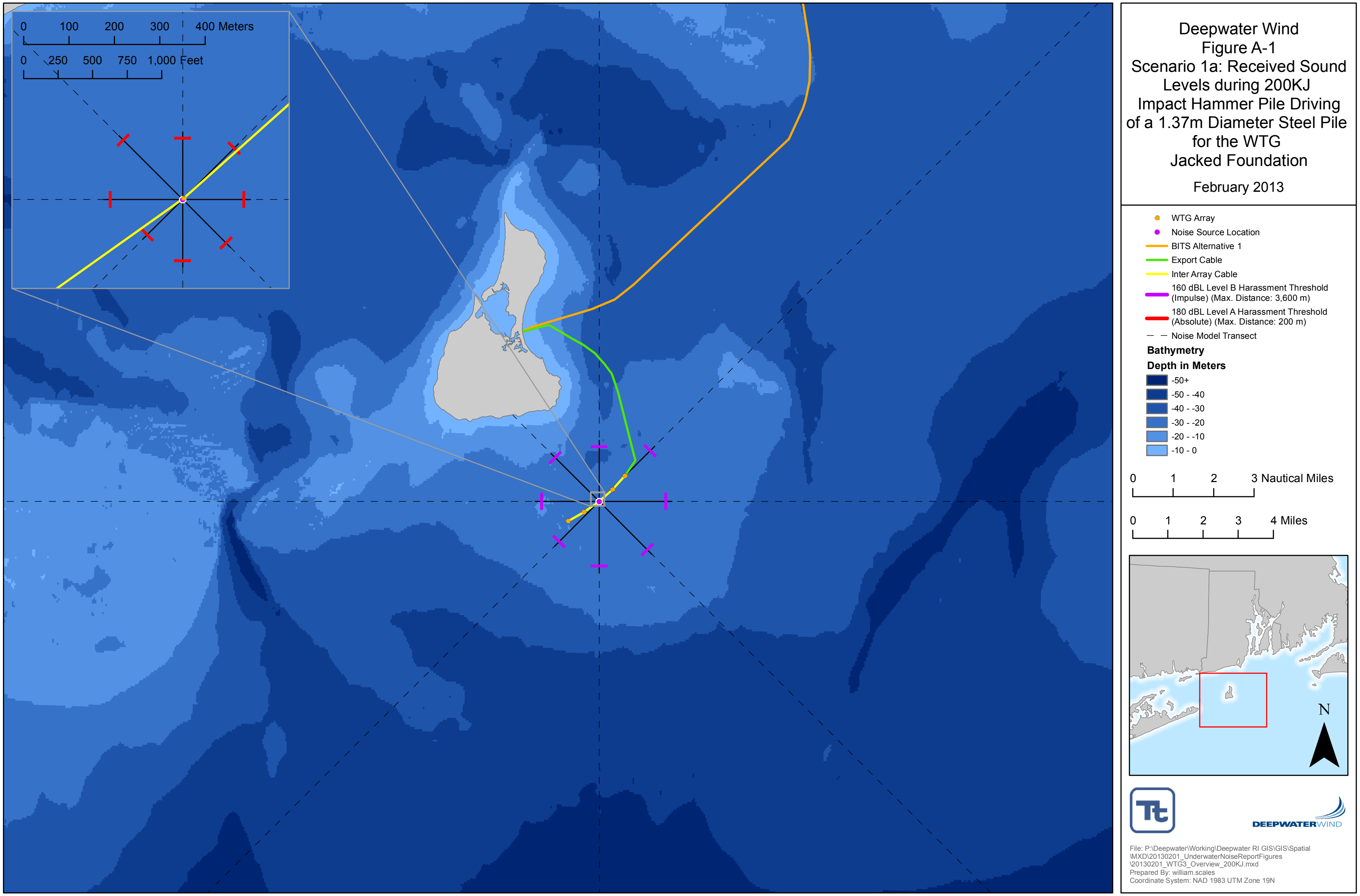


Figure A-2 Scenario 1b: Received Sound Levels during 600 KJ Impact Hammer Pile Driving of a 1.37 m Diameter Steel Pile for the WTG Jacked Foundation

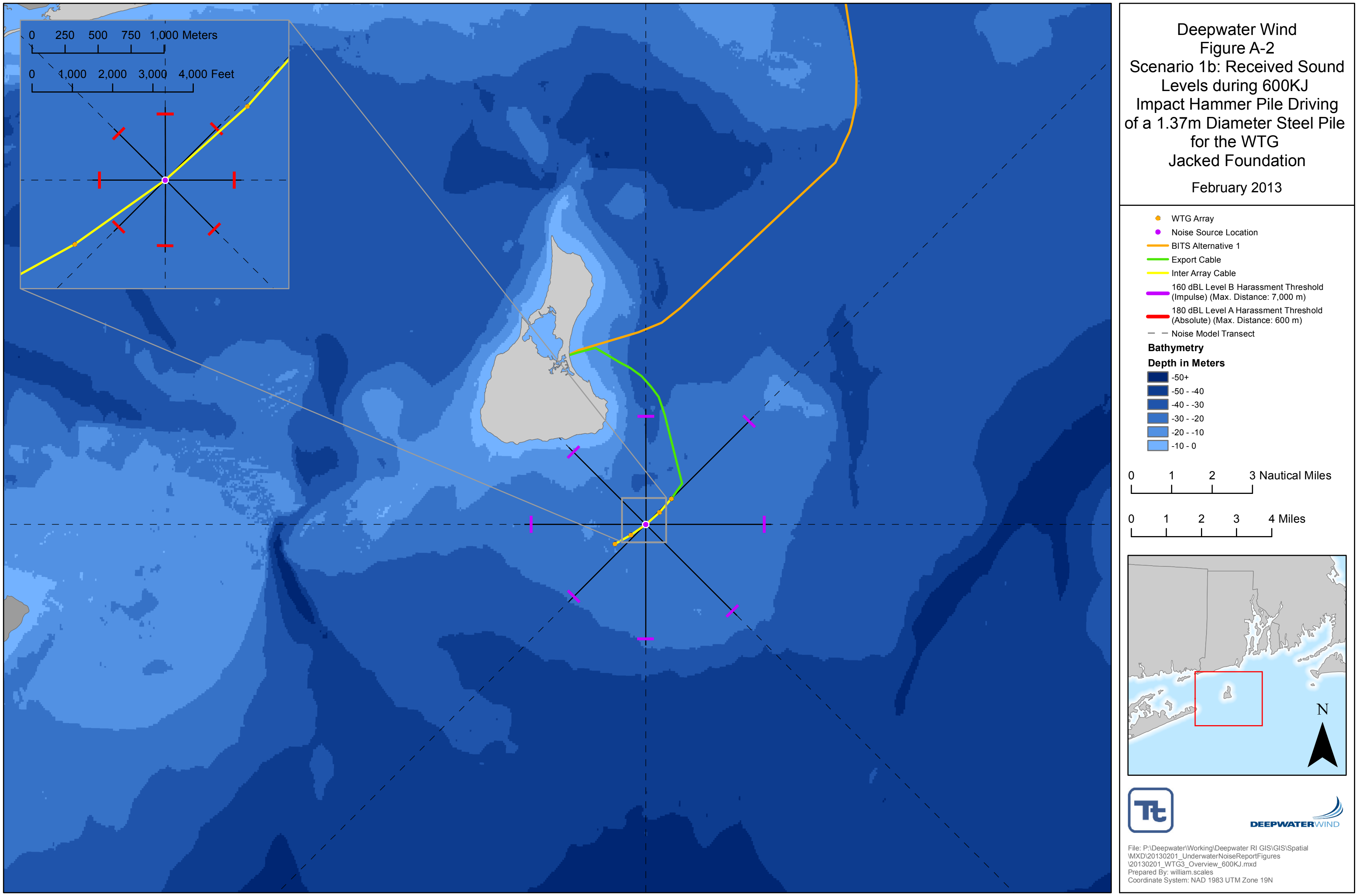


Figure A-3 Scenario 2a: Received Sound Levels during Vibratory Pile Driving of Sheet Pile during Cofferdam Construction – Narragansett

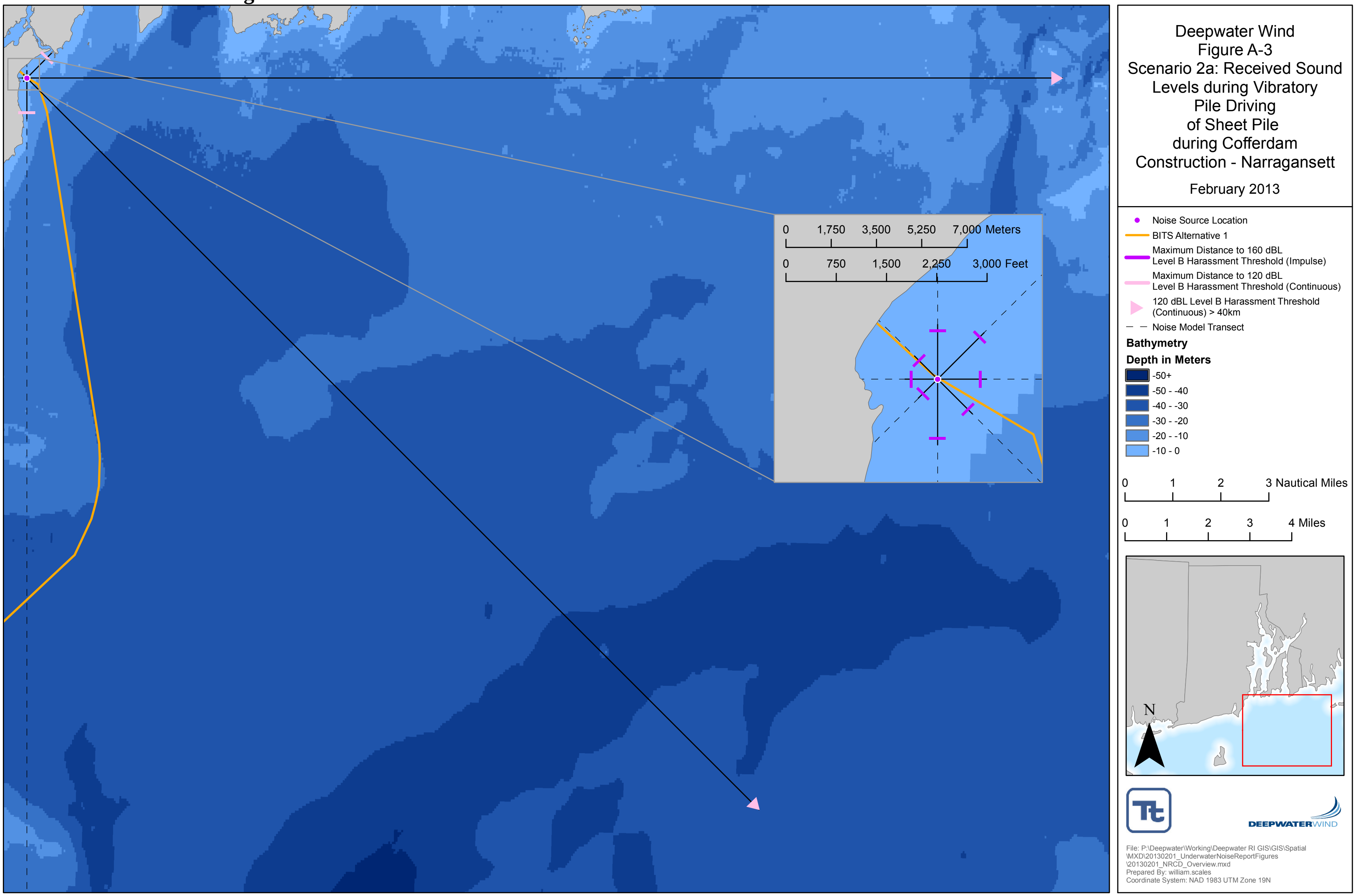


Figure A-4 Scenario 2b: Received Sound Levels during Vibratory Pile Driving of Sheet Pile during Cofferdam Construction – Block Island

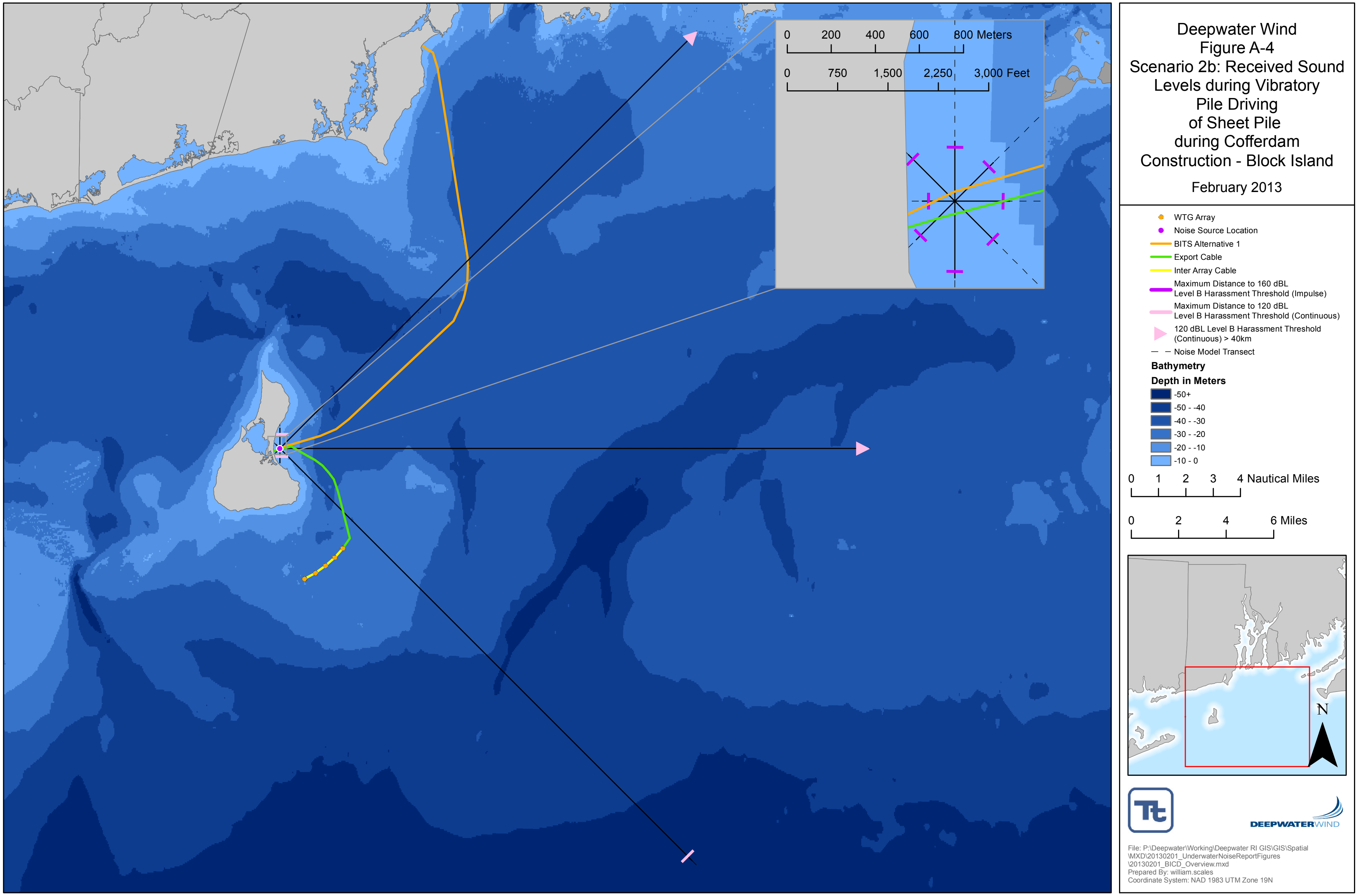


Figure A-5 Scenario 3: Received Sound Levels BITS Cablelay DP Vessel Maneuvering at Cable Location in 10 m water depth Thruster Power = 50%

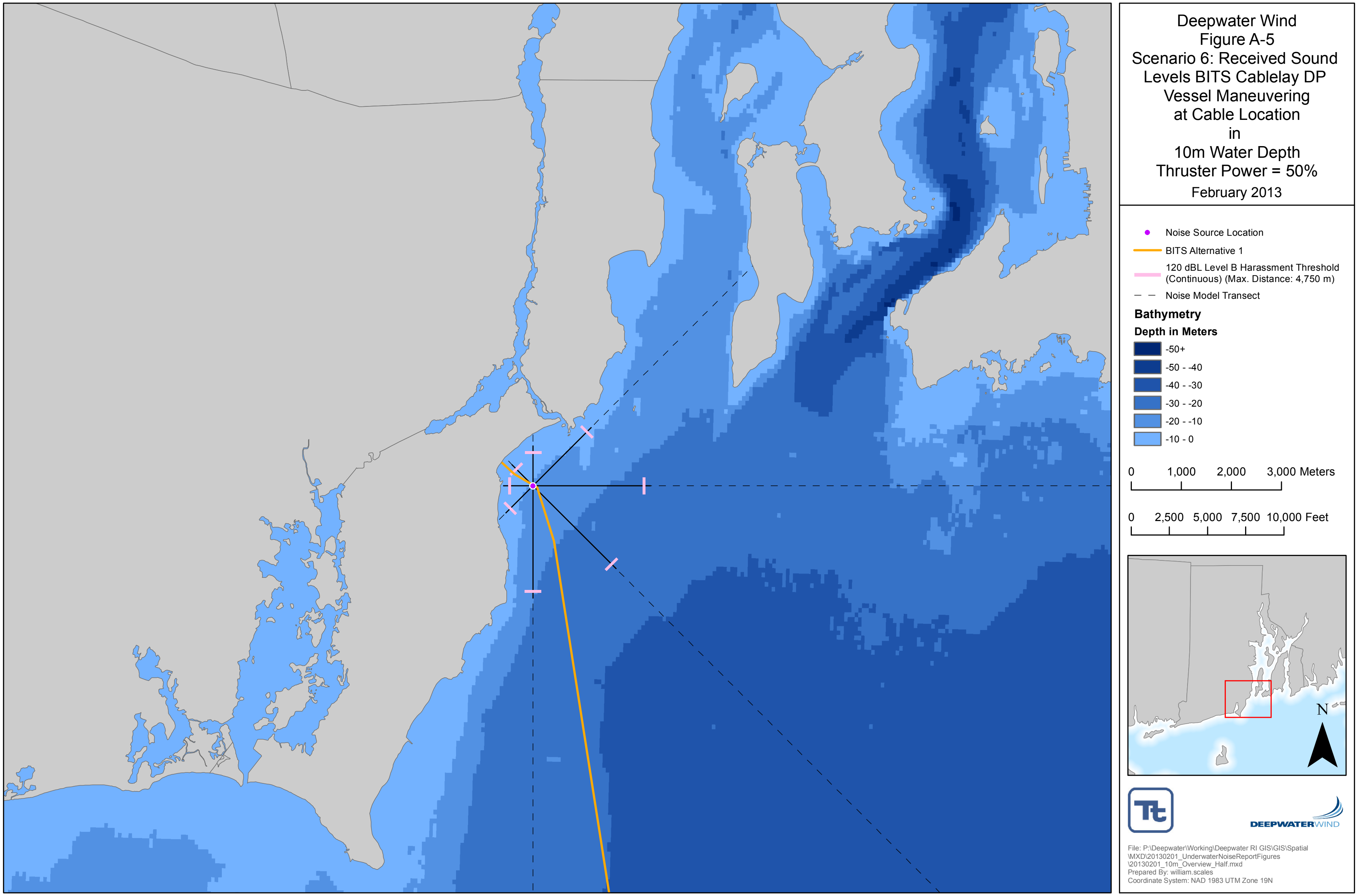


Figure A-6 Scenario 4: Received Sound Levels BIWF Export Cablelay DP Vessel Maneuvering at Cable Location in 20 m water depth Thruster Power = 50%

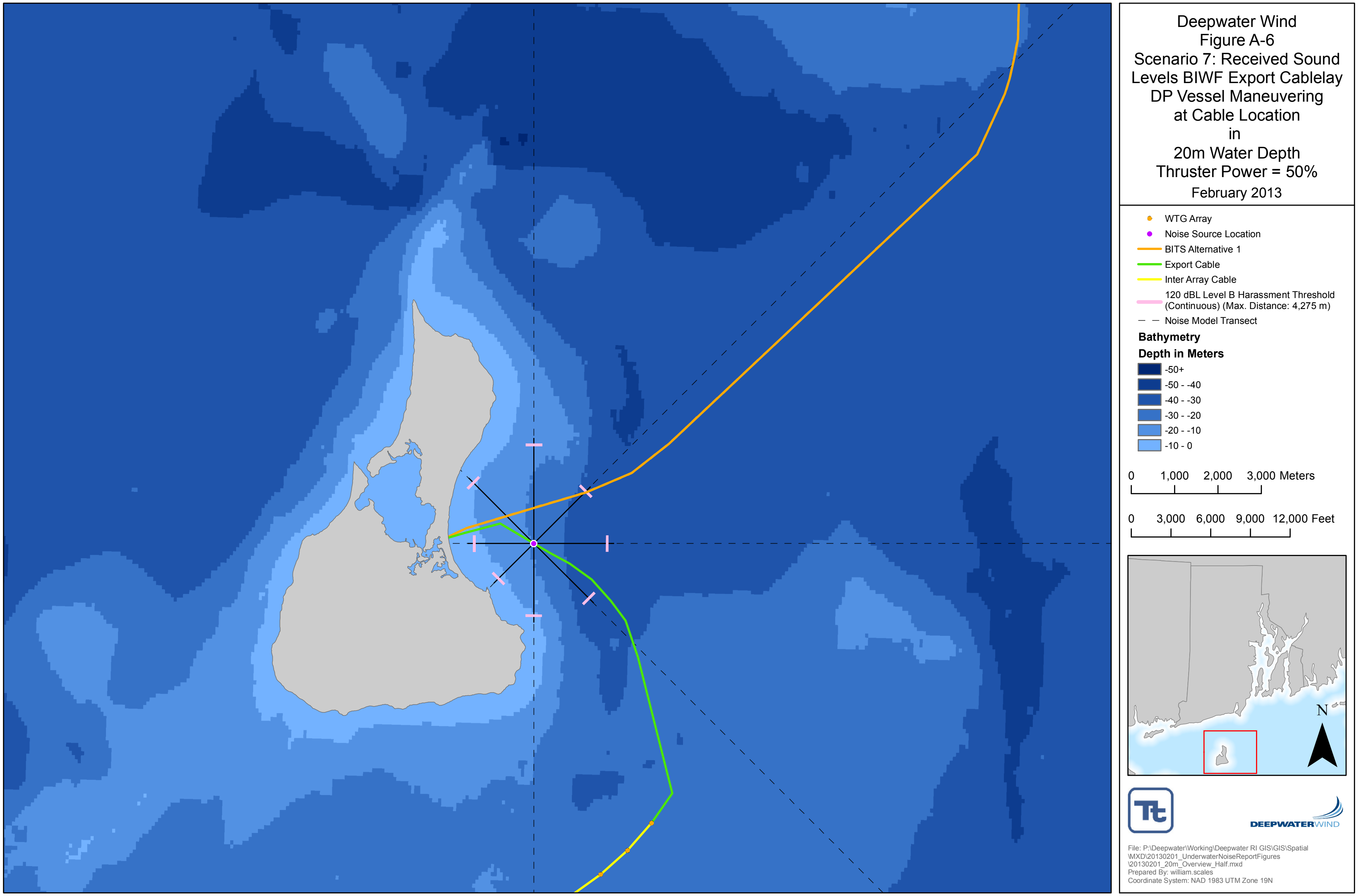
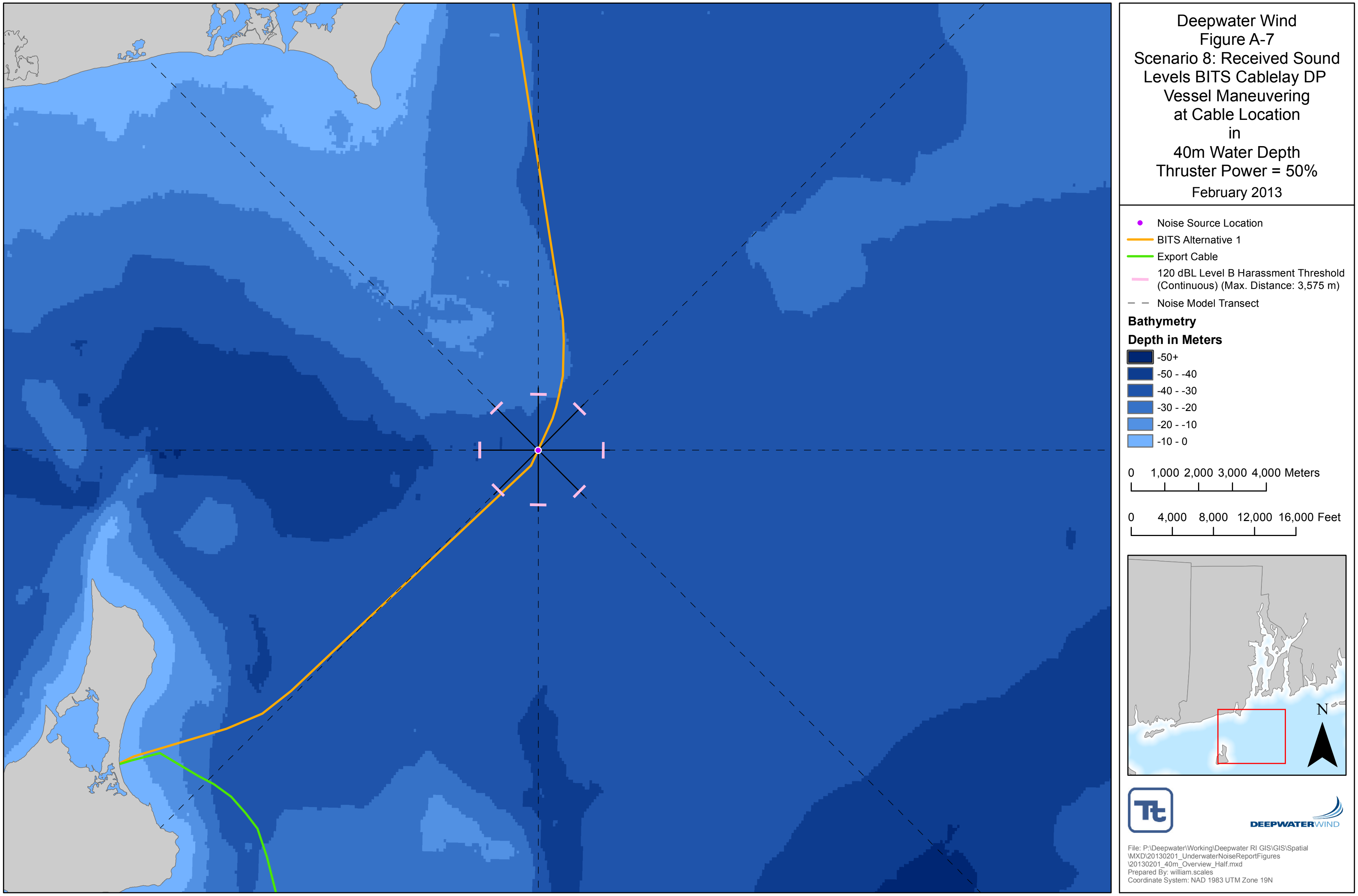


Figure A-7 Scenario 5: Received Sound Levels BITS Cablelay DP Vessel Maneuvering at Cable Location in 40 m water depth Thruster Power = 50%



APPENDIX B

Tables

Table B-1 Source Levels (dBL re 1 µPa·m)

Frequency (Hz)	Impact Pile Driver 200 KJ Force	Impact Pile Driver 600 KJ Force	Vibratory Pile Driver 1800 kN	Cable-Lay Vessel (Dynamic Positioning)	Wind Turbine
12.5	179	185	136	155.6	TBD
16	178	184	145	155.6	TBD
20	178	184	166	155.6	TBD
25	180	186	140	155.6	TBD
31.25	180	187	145	155.6	TBD
40	179	185	173	155.6	TBD
50	182	188	167	155.6	TBD
62.5	188	194	150	155.6	TBD
80	186	192	167	155.6	TBD
100	189	196	165	155.6	TBD
125	202	209	169	156.6	TBD
160	199	206	167	158	TBD
200	205	211	173	159.6	TBD
250	208	214	174	160.1	TBD
315	203	210	175	160.8	TBD
400	203	209	179	161.6	TBD
500	202	208	182	162	TBD
630	202	209	187	162.5	TBD
800	200	207	188	163.1	TBD
1000	199	205	189	162.9	TBD
1250	197	203	186	162.7	TBD
1600	191	198	185	162.4	TBD
2000	188	195	184	162.1	TBD
2500	188	194	180	161.6	TBD
3150	185	192	176	161.1	TBD
4000	184	190	172	160.7	TBD
5000	183	189	168	160.2	TBD
6300	182	188	164	159.6	TBD
8000	181	187	160	158.7	TBD
10000	180	186	156	157.7	TBD
12000	176	182	151	156.6	TBD
16000	171	177	147	156.6	TBD
20000	166	172	143	156.6	TBD

Table B-2 Distances to MMPA Thresholds, Impact Pile Driving (Hammer Energy = 600 kJ)

Transect Angle from Source	Distance to 180 dBL MMPA Threshold (m)	Distance to 160 dBL MMPA Threshold (m)
45	600	7000
90	575	5750
135	575	5900
180	550	5550
225	550	4975
270	550	5575
315	550	5000
360	550	5275

Table B-3 Distances to MMPA Thresholds, Impact Pile Driving (Hammer Energy = 200 kJ)

Transect Angle from Source	Distance to 180 dBL MMPA Threshold (m)	Distance to 160 dBL MMPA Threshold (m)
45	175	3600
90	175	3350
135	175	3425
180	150	3275
225	125	2900
270	175	2950
315	200	3150
360	150	2825

Table B-4 Distances to MMPA Thresholds, DP Vessel Maneuvering (Water Depth = 10 m, 50% Power)

Transect Angle from Source	Distance to 180 dBL MMPA Threshold (m)	Distance to 120 dBL MMPA Threshold (m)
45	--	2150
90	--	4750
135	--	4150
180	--	3850
225	--	775
270	--	600
315	--	600
360	--	800

Table B-5 Distances to MMPA Thresholds, DP Vessel Maneuvering (Water Depth = 20 m, 50% power)

Transect Angle from Source	Distance to 180 dBL MMPA Threshold (m)	Distance to 120 dBL MMPA Threshold (m)
45	--	3375
90	--	4275
135	--	4125
180	--	2100
225	--	1325
270	--	1700
315	--	2200
360	--	3475

Table B-6 Distances to MMPA Thresholds, DP Vessel Maneuvering (Water Depth = 40 m, 50% power)

Transect Angle from Source	Distance to 180 dBL MMPA Threshold (m)	Distance to 120 dBL MMPA Threshold (m)
45	--	3450
90	--	3575
135	--	3375
180	--	3450
225	--	3550
270	--	3575
315	--	3350
360	--	2975

Table B-7 Distances to MMPA Thresholds, Vibratory Pile Driving (Block Island)

Transect Angle from Source	Distance to 180 dBL MMPA Threshold (m)	Distance to 160 dBL MMPA Threshold (m)	Distance to 120 dBL MMPA Threshold (m)
45	--	250	>40000
90	--	250	>40000
135	--	275	39500
180	--	350	1000
225	--	250	400
270	--	150	200
315	--	300	400
360	--	275	1400

Table B-8 Distances to MMPA Thresholds, Vibratory Pile Driving (Narragansett)

Transect Angle from Source	Distance to 180 dBL MMPA Threshold (m)	Distance to 160 dBL MMPA Threshold (m)	Distance to 120 dBL MMPA Threshold (m)
45	--	300	1350
90	--	225	>40000
135	--	225	>40000
180	--	300	1600
225	--	125	200
270	--	150	200
315	--	150	200
360	--	250	300